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Preparatory to developing mission profiles for future attack, crane, observation, assault, transport, and utility helicopters, the flight condition recognition (FCR) technique was applied to some 10-hour data samples for each of the following class-model helicopters which had acquired 200 or more hours of multichannel oscillograph data during operational usage surveys while the helicopters operated under combat conditions in Southeast Asia

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20. (SEA): attack - AH-1G, crane - CH-54A, observation - OH-6A, assault - UH-1H, transport - CH-47A, and utility - UH-1H. The resultant SEA operational mission profiles for each of the six helicopter classes consisted principally of an operational usage spectrum where 22 flight conditions in one or more of 10 mission segments are expressed both as the number of occurrences per 100 hours of mission time and as the percentage of time expended in the total mission time. The comparison of design and Navy AR-56 mission profiles with the SEA profiles with and without ground time revealed appreciable and sometimes drastic differences. Based primarily on the SEA operational mission profiles and on the mission requirements of advanced helicopters in low-, mid-, and high-intensity warfare operations, the mission profiles for each of the six classes of future helicopters are in a uniform and standardized format best suited for design and fatigue analysis studies and contain common figures and tables along with the corresponding SEA data to permit ready comparisons between the two sets of data as well as between the profile for one helicopter class with that for any of the other classes.

EUSTIS DIRECTORATE POSITION STATEMENT

This report presents the results of an effort to develop a realistic mission profile for each of six helicopter types in current and future Army inventories: observation, utility, utility/tactical assault, attack, crane, and transport. The profiles that were developed are the product of operational data which had been gathered over two decades, starting with early NACA efforts and including extensive studies conducted by the U. S. Army Air Mobility Research and Development Laboratory.

The report presents mission profiles that have been developed from a broad data base and integrates techniques and approaches used by the several helicopter manufacturers into a consistent method for deriving the mission profile for the six helicopter types. Results of this program are immediately usable but also indicate that additional work is desirable to refine and verify the load factor distribution techniques.

This report has been reviewed by this Directorate and is considered to be technically sound. The technical monitor for this contract was Mr. Arthur J. Gustafson, Jr., Technology Applications Division.

PREFACE

Technology Incorporated, Dayton, Ohio, prepared this report in compliance with the requirements of Contract DAAJ02-74-C-0017. The program was sponsored by the Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia. The project monitor for the Army was Mr. Arthur J. Gustafson, Jr.

In this program, the ultimate objective was the development of uniform and standardized mission profiles and design criteria for future helicopters in the attack, crane, observation, assault, transport, and utility classes.

The program was conducted under the direction of Mr. R. B. Johnson, Manager, Systems Analysis Department. The Project Engineer was Mr. S. W. Russell. Mrs. R. Meyers directed the data processing, and Mr. T. L. Cox coordinated the interpretation of the processed data and the subsequent development of operational mission profiles and their comparison with manufacturer's design and Navy AR-56 mission profiles.

The authors are grateful to Mr. Johnson for his guidance and contribution and to Lt. Colonel Rumney and Captain Herndon, both of the Cavalry and Aviation Systems Division in the Directorate of Combat Development at Fort Knox, Kentucky, for their information on the mission requirements and flying techniques for future combat helicopters.

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1. INTRODUCTION

1.1 BACKGROUND

In the design and manufacture of helicopters, each airframe manufacturer has defined the design mission profiles as those that would be best suited to his type of helicopter. As a result, the description and discreteness of design mission profiles vary considerably among the helicopter manufacturers. Consequently, there is need in the present development of the design process to define mission profiles which reflect actual operational usage and to establish uniform design criteria for each helicopter class. The standardization of the design mission profiles for each helicopter class will provide a common base for comparing the structural performance of future helicopters intended to meet the same operational requirements.

During the past 10 years a large amount of operational helicopter data have been collected, processed, and documented. The format of the data presentation was based on the premise that helicopter designers would utilize a statistical combination of operational parameters. However, the fatigue analyst needs discrete information concerning the frequency, duration, and severity of specific flight conditions. Therefore, to properly utilize the previously collected data, each flight condition must be defined in terms of the recorded parameters, and the frequency of the parameter combinations must be determined.

1.2 FCR TECHNIQUE

To facilitate the direct utilization of operational usage data in establishing fatigue design criteria for future Army helicopters, Technology Incorporated developed the flight condition recognition (FCR) technique for processing the operational usage data recorded on oscillograms. As a qualitative method, the FCR technique differs from the previous processing methods in that more mission segments are used to group the data and more specific flight conditions are identified in each mission segment. After the mission segments and flight conditions are demarcated on the oscillograms, the frequency and duration of these conditions are measured for the subsequent derivation of a more realistic operational usage spectrum. Such a spectrum is of prime importance to the fatigue analyst in determining the fatigue lives of helicopter components and in establishing design criteria for future helicopters.

1.3 PROGRAM OBJECTIVE AND SCOPE

Accordingly, to demonstrate that the FCR technique could be used to develop operational mission profiles for each of six

helicopter classes (attack, crane, observation, assault, transport, and utility), this technique was applied to a small sample of oscillogram data recorded in Southeast Asia (SEA) on each of the five aircraft listed in Table 1.

TABLE 1. HELICOPTERS INCLUDED IN THE STUDY, BY CLASS

Class	Aircraft Model and Manufacturer
Attack	AH-1G Bell Helicopters
Crane	CH-54 Sikorsky Aircraft
Observation	OH-6A Hughes Helicopters
Assault	UH-1H Bell Helicopters
Transport	CH-47 Boeing-Vertol
Utility	UH-1H Bell Helicopters

Although the derived profiles are accurate representations of the small data samples, they are subject to refinement with the subsequent application of the FCR technique to larger and more comprehensive data samples.

The resulting mission profiles include the following types of data for each helicopter class:

(1) The frequency of flight conditions and the percentage of total mission time spent in performing them with a breakdown by mission segment.

(2) The average outside-of-threshold (0.8g to 1.2g) duration of maneuver vertical load factors (n_z's) in n_z ranges with a breakdown by mission segment and flight condition.

(3) The frequency of maneuver n_z's in n_z versus coincident gross weight and c.g. ranges and the percentage of total mission time spent in all coincident gross weight and c.g. ranges.

(4) The frequency of landing impact Δn_z's after landings from descent and hover and of taxi Δn_z's in Δn_z versus gross weight ranges.

For each of the six helicopter classes, the operational mission profiles including ground time were converted to the format of the manufacturer's design mission profiles and then compared with the latter. Additionally, the operational profiles were similarly compared with the profiles given in the Navy specification AR-56, "Structural Design Requirements (Helicopters)."

While the time for the ground operations in the SEA operational mission profiles ranged from 9.4 to 40.0 percent of the total mission time, principally because of their inclusion of steady-state ground conditions, the corresponding time in the manufacturer's design and the AR-56 mission profiles accounted for only some 1 percent of the total mission time except for that in the CH-54A design profile which represented 2.11 percent of the total mission time. Therefore, to more realistically compare the times for the in-flight operations, all ground time was deleted from the operational usage spectrum as adapted to the design and AR-56 formats and the remaining percentages of time were normalized to 100 percent. In the subsequent comparisons, only the major substantiations or changes were noted.

Finally, for each of the six helicopter classes, mission profiles were developed for future helicopters with their higher performance and maneuver capabilities. Including the SEA operational profile data to permit ready comparisons, these future profiles were based primarily on the mission requirements for the anticipated low-, mid-, and high-intensity warfare operations, as defined in the literature and described by pilots proficient in current and advanced tactics, as well as on the operational mission profiles. Although the profiles for the future helicopters were based on extrapolations of small data samples and therefore are subject to refinement with the subsequent FCR application to larger and more pertinent data samples, they are reasonable and practical projections. In a uniform and standarized format best suited for fatigue analysis and design studies, each profile consists of the following:

(1) A tabular spectrum of mission segment-flight condition frequency (expressed as either the percentage of total mission time that the helicopter performs a given flight condition in a mission segment or the number of the flight condition occurrences in a mission segment per unit time).

(2) A histogram of the airspeed frequency distribution.

(3) An exceedance curve type of cumulative maneuver n_z distribution.

(4) A table of the percentage of mission time for maneuver n_z's outside the n_z threshold.

(5) A histogram of the landing impact occurrences with Δn_z's above the n_z threshold per unit time.

(6) An exceedance curve type of cumulative taxi Δn_z distribution.

1.4 VALIDITY OF DATA SAMPLE AND FCR TECHNIQUE

As a pilot study to demonstrate the effectiveness of the FCR technique in deriving operational mission profiles, this program used only some 10 hours of the previous SEA oscillogram data recorded on each of the five helicopter models. As detailed in Appendix A, the data were grouped in 10 mission segments. The same data had previously been edited by the four-mission-segment technique.[1,2,3,4,5] In this technique, however, the four mission segments--ascent, maneuver, descent, and steady state--are defined somewhat differently than the corresponding mission segments for the FCR method. Therefore, to determine how representative the data sample is of the previous report data with its much larger data representation, the four-mission-segment technique was applied to the data sample to obtain percentages of time in the four mission segments that could be directly compared with those for the

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[1] Giessler, F. Joseph, Nash, John F., and Rockafellow, Ronald I., FLIGHT LOADS INVESTIGATION OF AH-1G HELICOPTERS OPERATING IN SOUTHEAST ASIA, Technology Incorporated, Dayton, Ohio; USAAVLABS Technical Report 70-51, U.S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, September 1970, AD 878039.

[2] Giessler, F. Joseph, Nash, John F., and Rockafellow, Ronald I., FLIGHT LOADS INVESTIGATION OF CH-54A HELICOPTERS OPERATING IN SOUTHEAST ASIA, Technology Incorporated, Dayton, Ohio; USAAVLABS Technical Report 70-73, Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, January 1971, AD 881 238.

[3] Giessler, F. Joseph, Clay, Larry E., and Nash, John F., FLIGHT LOADS INVESTIGATION OF OH-6A HELICOPTERS OPERATING IN SOUTHEAST ASIA, Technology Incorporated, Dayton, Ohio; USAAMRDL Technical Report 71-60, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, October 1971, AD 738202.

[4] Johnson, Raymond B., Clay, Larry E., and Meyers, Ruth E., OPERATIONAL USE OF UH-1H HELICOPTERS IN SOUTHEAST ASIA, Technology Incorporated, Dayton, Ohio; USAAMRDL Technical Report 73-15, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, May 1973, AD 764260.

[5] Giessler, F. Joseph, and Braun, Joseph F., FLIGHT LOAD INVESTIGATION OF CARGO AND TRANSPORT CH-47A HELICOPTERS OPERATING IN SOUTHEAST ASIA, Technology Incorporated, Dayton, Ohio; USAAVLABS Technical Report 68-2, U.S. Army Aviation Materiel Laboratories, Fort Eustis, Virginia, April 1968, AD 672 842.

report data. As apparent in Figure 1, which compares the percentages for the two sets of data, the sample data, with the exception of the CH-54A steady-state data, compare very closely with the report data.

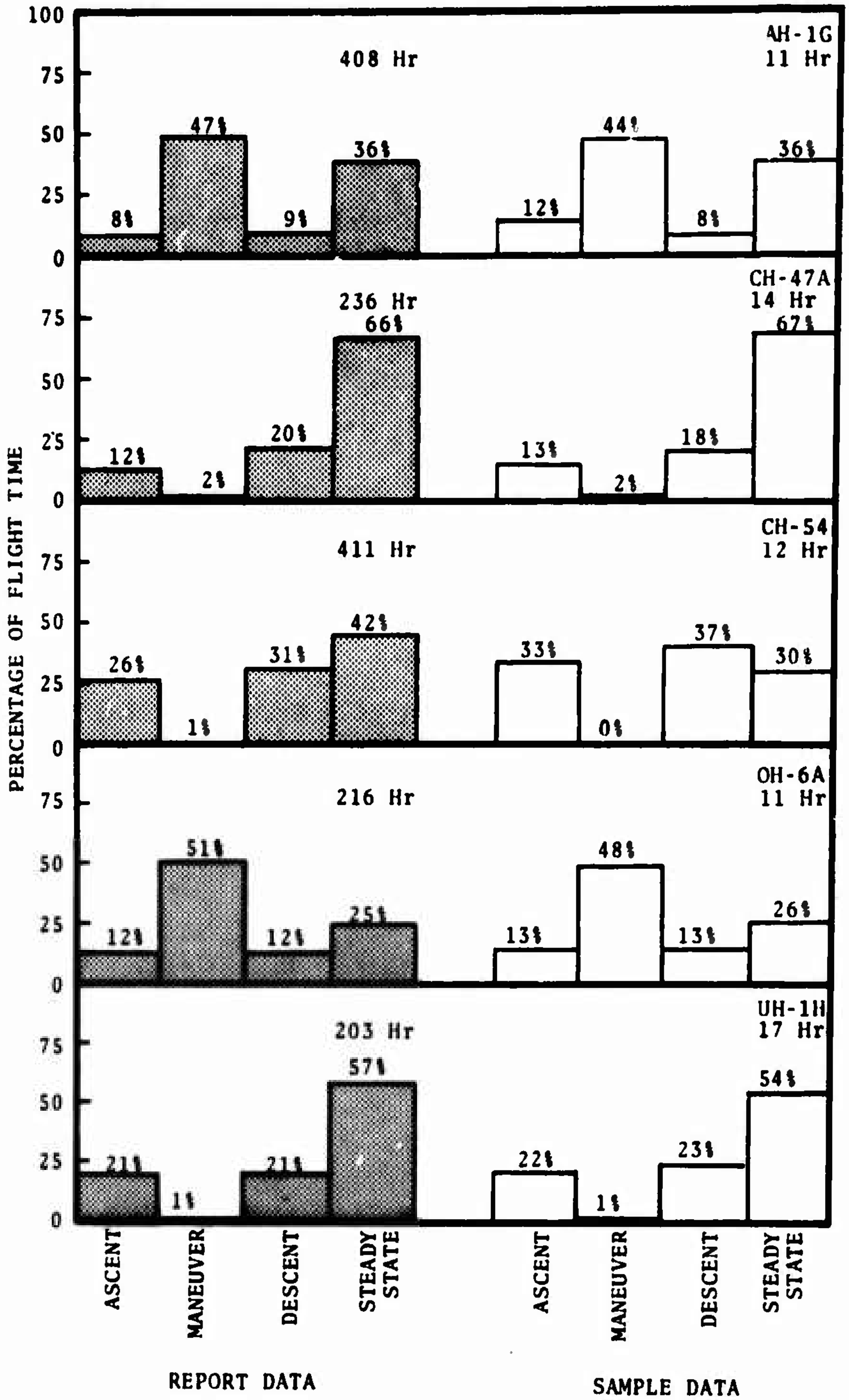


Figure 1. Comparison of Sample Data and Report Data for Each Helicopter Type.

However, the four-mission-segment method does not represent the data as definitively as the FCR technique, as illustrated in the following: For each of the four mission segments in the four-mission-segment method, Figures 2 through 7 (for the six helicopter class-model categories in Table 1)

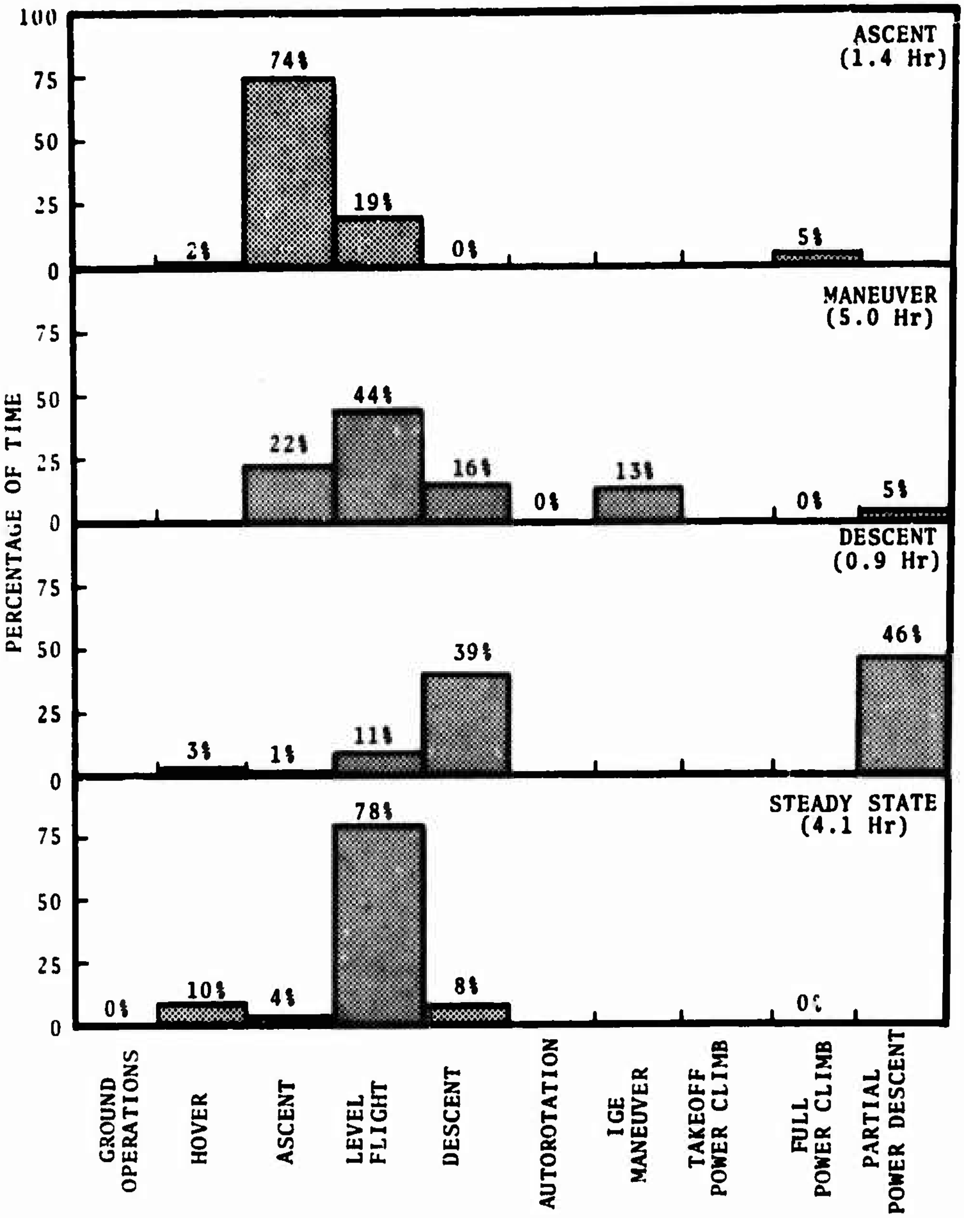


Figure 2. AH-1G Four-Mission-Segment Data Distributed in the FCR Mission Segments.

distribute the percentage of time in the 10 FCR mission segments. As apparent, the FCR method reflects the operational usage better. For example, in Figure 2 for the AH-1G, ascent as derived by the four-mission-segment technique includes the hover, ascent, level flight, and full power climb mission segments as derived by the FCR technique.

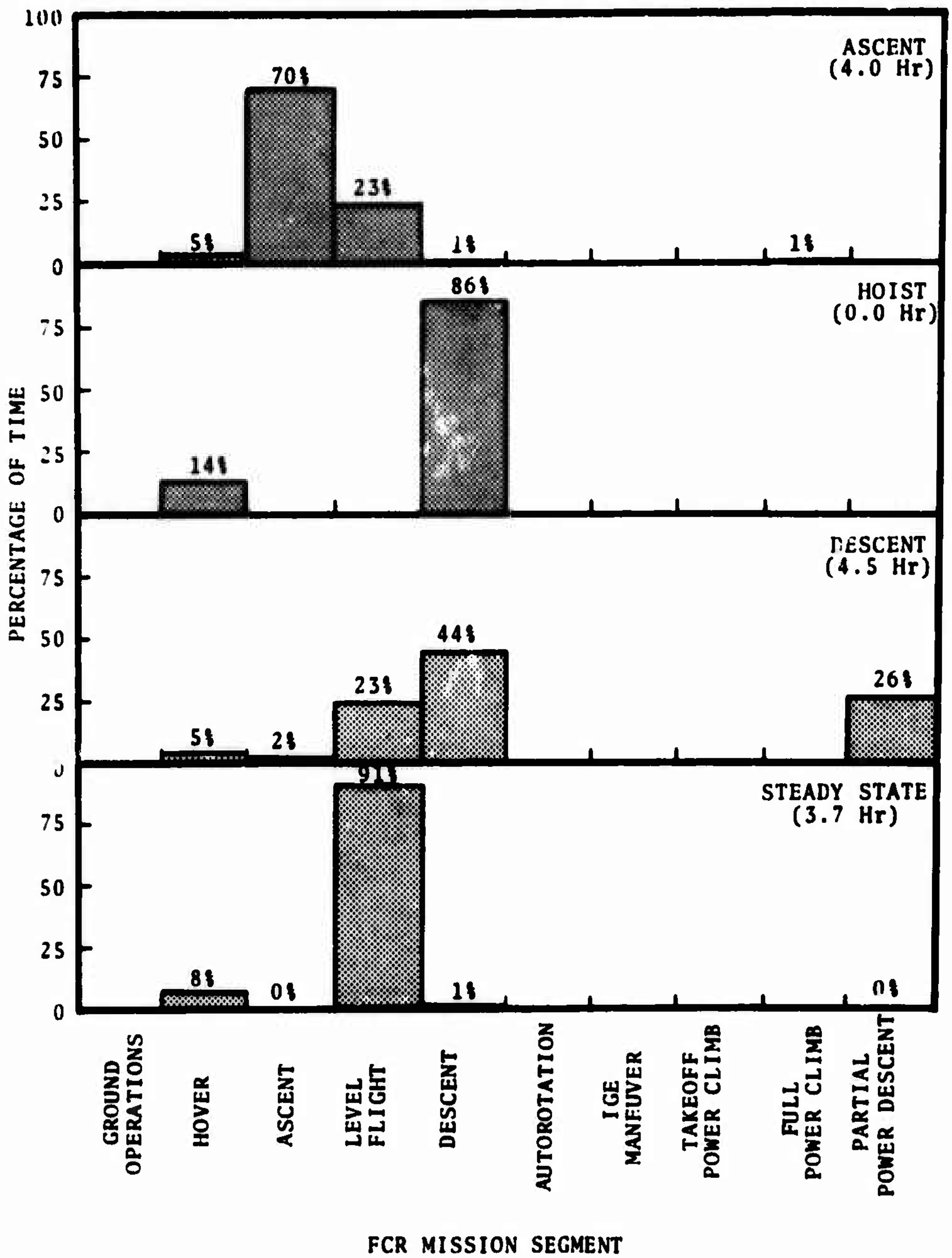


Figure 3. CH-54A Four-Mission-Segment Data Distributed in the FCR Mission Segments.

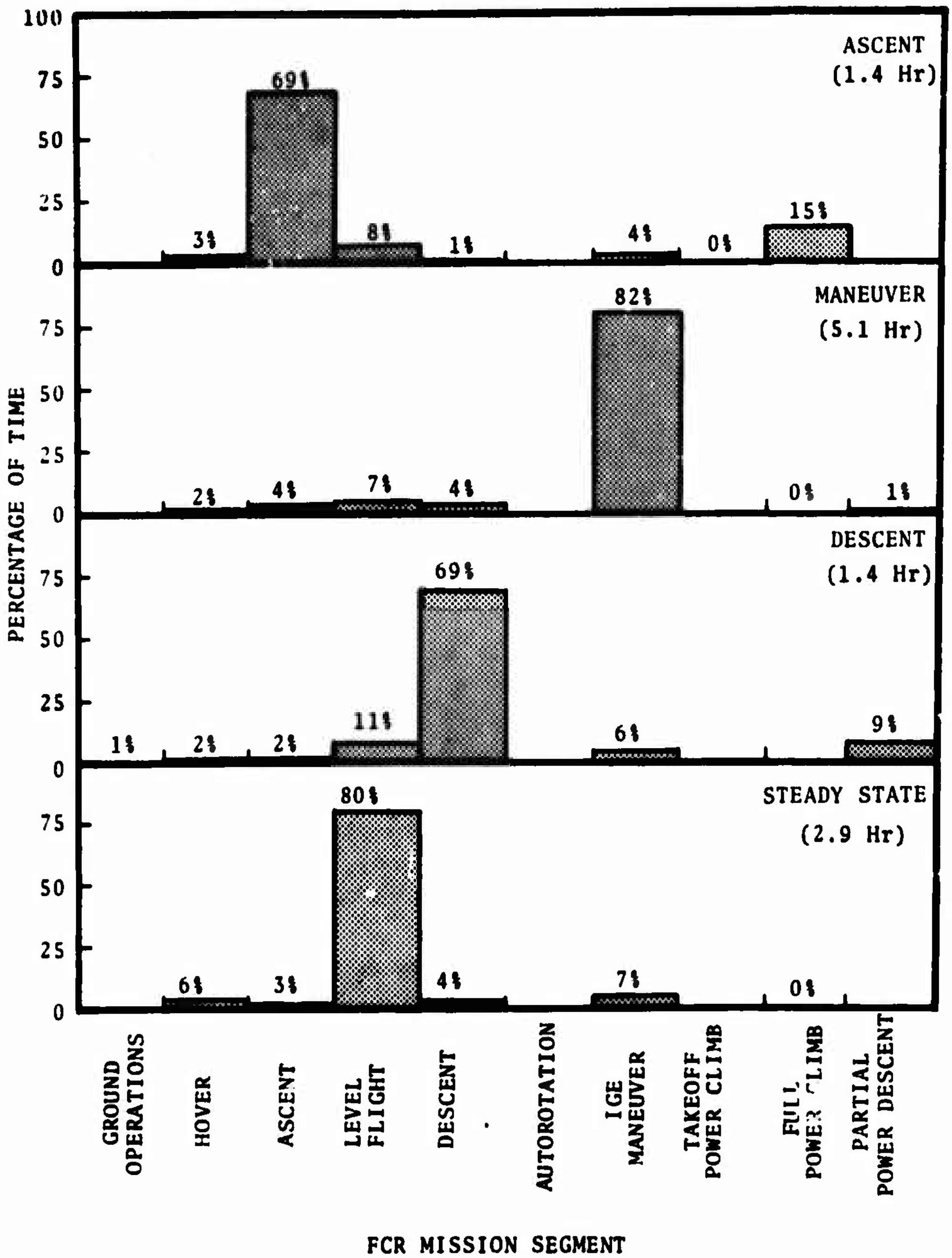


Figure 4. OH-6A Four-Mission-Segment Data Distributed in the FCR Mission Segments.

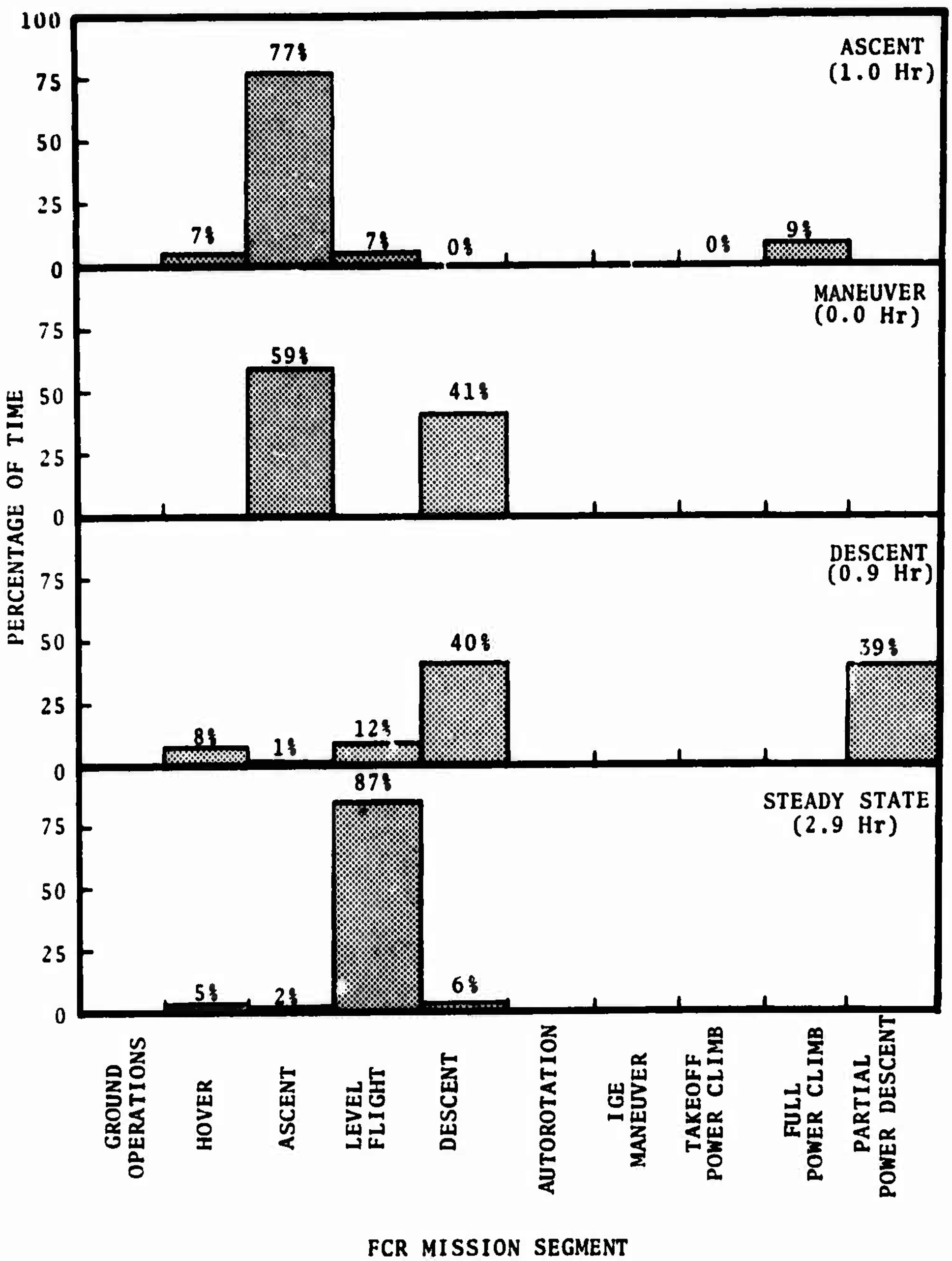


Figure 5. UH-1H Assault Four-Mission-Segment Data Distributed in the FCR Mission Segments.

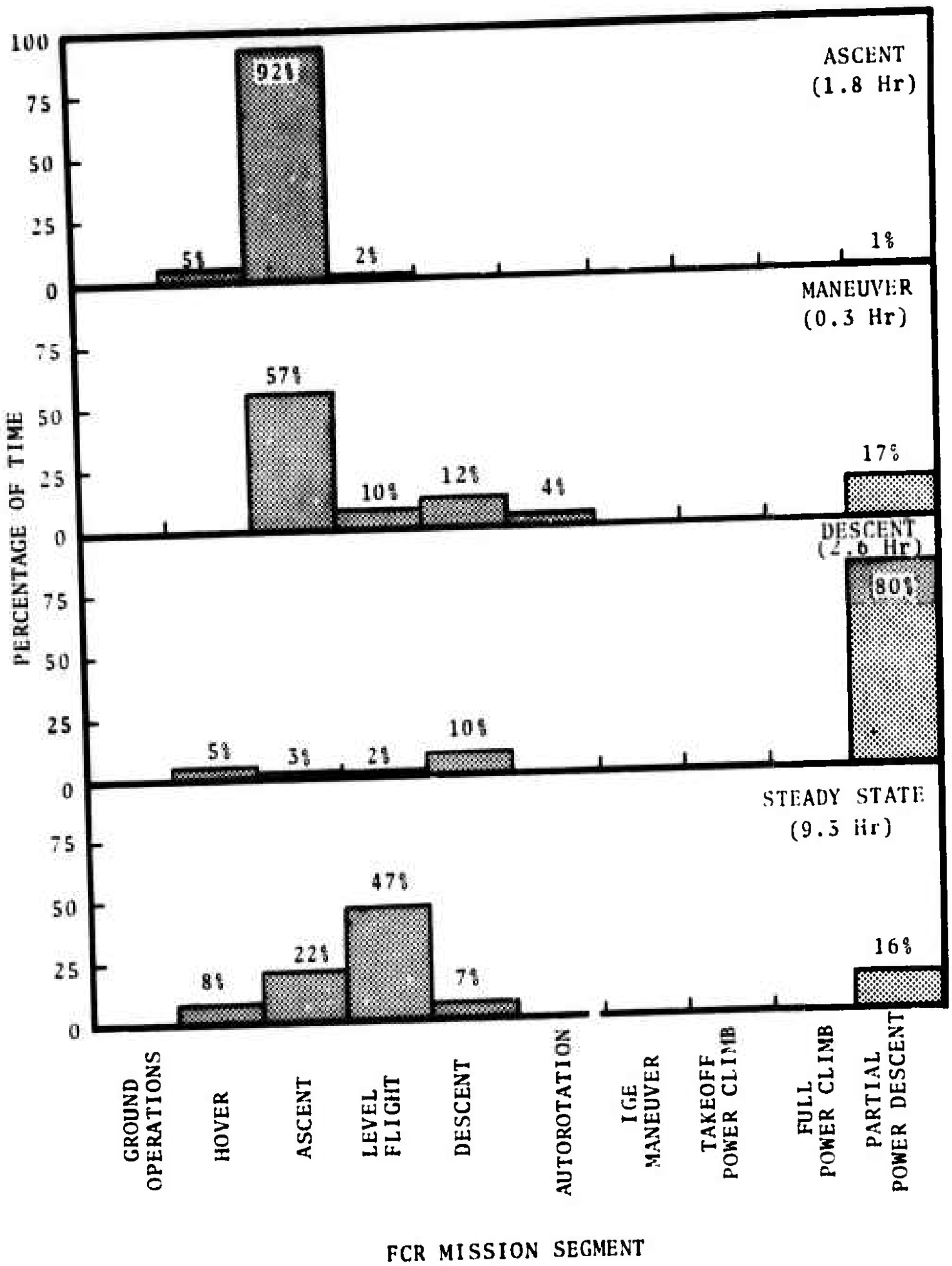


Figure 6. CH-47A Four-Mission-Segment Data Distributed in the FCR Mission Segments.

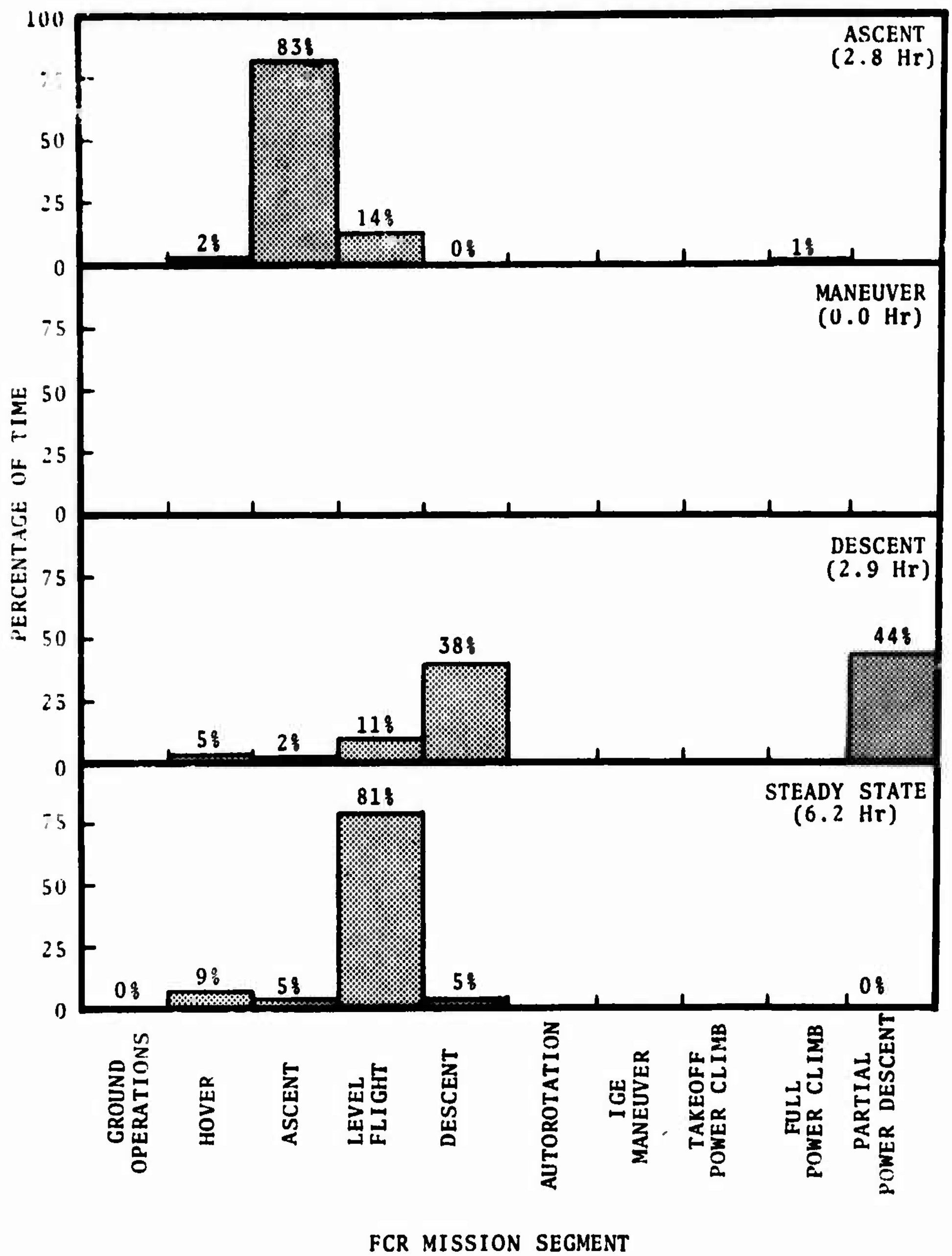


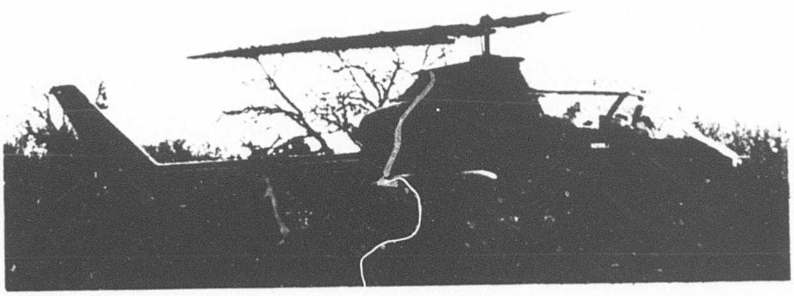
Figure 7. UH-1H Utility Four-Mission-Segment Data Distributed in the FCR Mission Segments.

1.5 HELICOPTER MODEL-CLASS CATEGORIES

The following paragraphs describe the helicopters which represent the six helicopter classes (see Table 1) and which yielded the SEA data sample used to derive the operational mission profiles.

1.5.1 Bell AH-1G Representing the Attack Class Helicopters

The AH-1G "Huey Cobra" helicopter is a highly maneuverable, high-speed gun ship. Deployed as a ground-support weapons platform, the AH-1G has a controllable nose turret and two external store pylons. The nose turret contains a 7.67-mm minigun and a 40-mm grenade launcher, and each of the pylons carries such armament as the XM-159C, XM-157, XM-18, and XM-159. The crew consists of a pilot and a copilot/gunner. To illustrate the general configuration of the AH-1G, Figures 8 and 9 present a photo and a multiview drawing of this helicopter model. In addition, Figure 8 contains basic data identifying some of the aircraft operational characteristics and limitations.



Characteristics

disc area	1520 sq ft
rotor solidity	0.652
airfoil section	9-1/3T special symmetrical
wing area	28.2 sq ft
engine	Lycoming T52-L-13
des. max. gross wt.	9500 lb
empty weight	5382 lb

Limitations

normal rate power	1250 shp
takeoff power	1400 shp
usable power (transmission limit)	1100 shp
usable power/des. max. gross wt.	0.116
max. airspeed (1100 hp)	158 kn
max. allowable airspeed	190 kn

Figure 8. Photograph of AH-1G Helicopter.

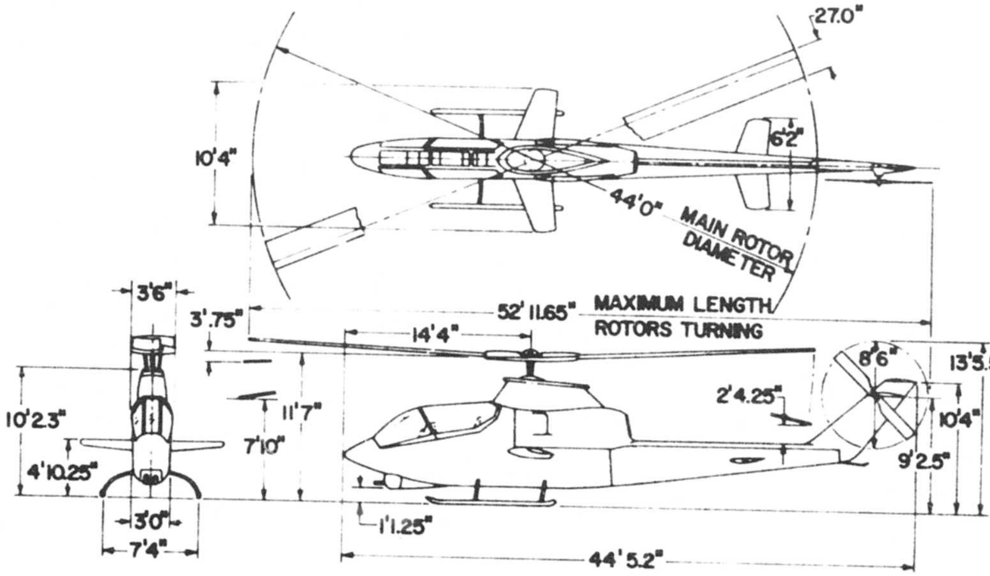
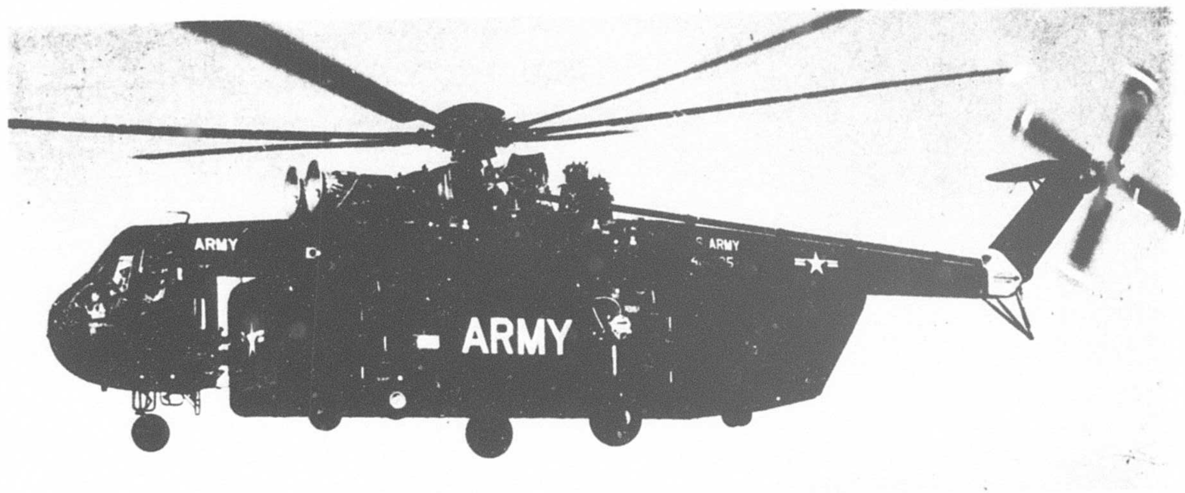


Figure 9. Multiview Drawing of AH-1G Helicopter.

1.5.2 Sikorsky CH-54A Representing the Crane Class Helicopters

The CH-54A "Skycrane" helicopter is a twin-turbine-engine six-bladed single-rotor heavy-lift aircraft designed to carry outsized payloads or special-purpose vans or pods from either a single-point or a four-point suspension system. The single-point suspension system features a 100-foot cable with a hydraulically operated hoist and an electrically actuated hook. Loads can be raised or lowered at a rate of 50 feet per minute. Twenty thousand pounds can be carried with the winch locked at a selected cable length. The four-point system uses four 6000-pound-capacity hoists mounted at hard points on the side of the fuselage. Each hoist has 50 feet of cable and a damping device to isolate aircraft load vibration. The crew consists of a pilot, a copilot, and an aft-facing hoist operator. Figures 10 and 11 present a photo and multiview drawing of this helicopter model. Additionally, Figure 10 contains basic data identifying some of the aircraft operational characteristics and limitations.



Characteristics	
rotor diameter	72 ft
rotor solidity	0.08649
engines (two)	P&W JFTD-12A-4A
des. max. gross Wt.	42,000 lb
empty weight	19,234 lb

Limitations	
normal rated power	*4000 shp
takeoff power	*4500 shp
usable power (continuous)	*4000 shp
usable power/des. max. gross weight	0.0953
max. allowable airspeed	110 kn

*each engine

Figure 10. Photograph of CH-54A Helicopter.

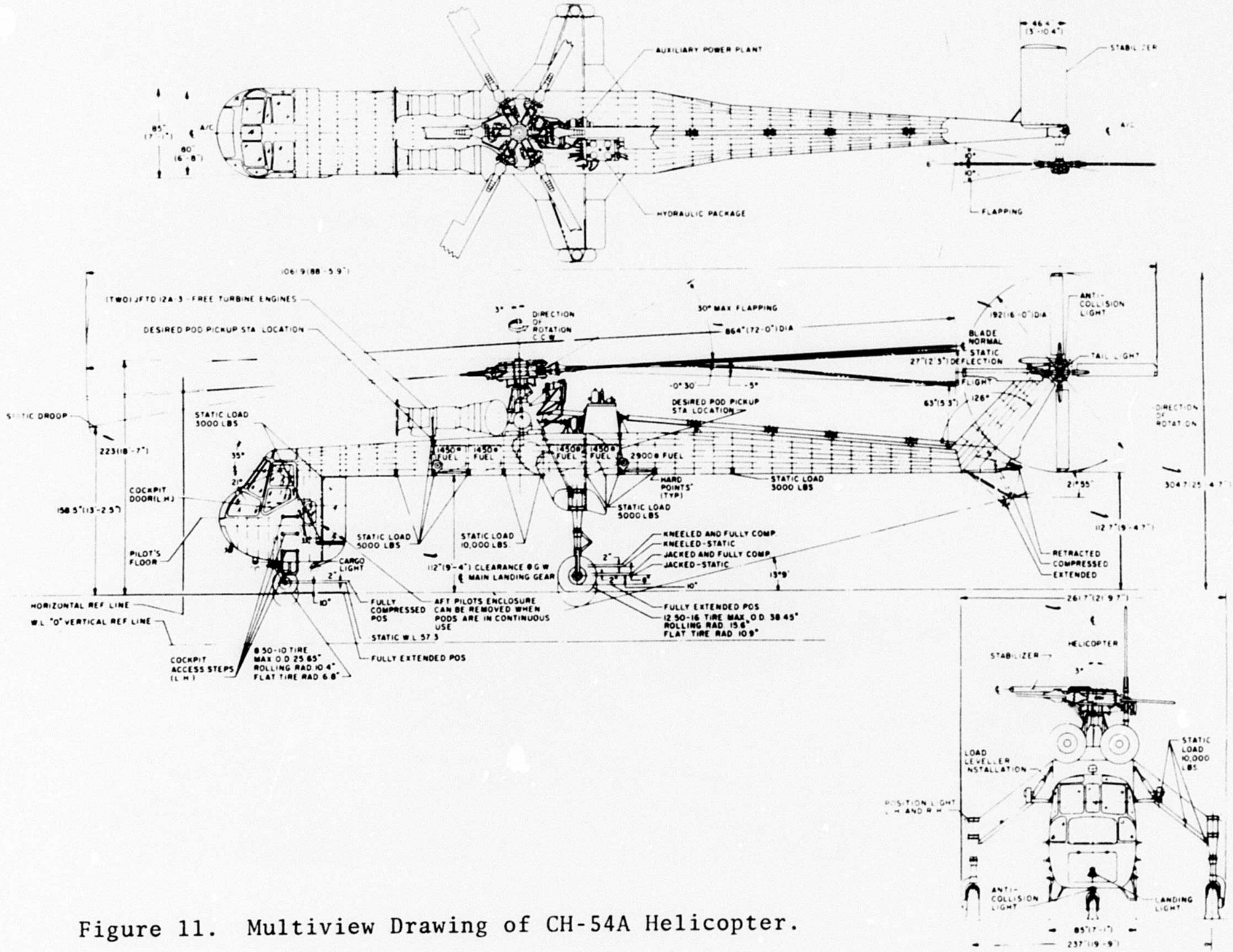
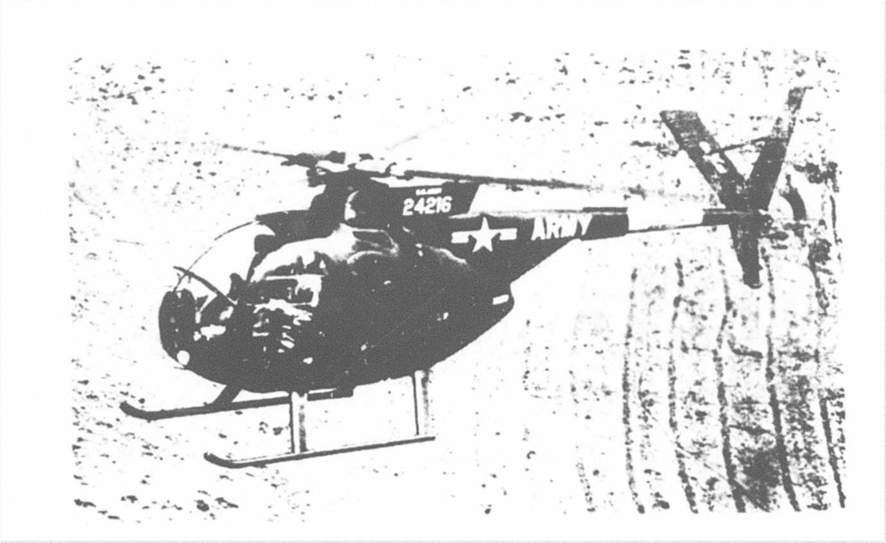


Figure 11. Multiview Drawing of CH-54A Helicopter.

1.5.3 Hughes OH-6A Representing the Observation Class Helicopters

The OH-6A is an all-metal, single-engine helicopter. A single four-bladed, fully articulated main rotor provides lift, and a tail rotor provides antitorque and directional control. In addition to a photograph (Figure 12) and a multi-view drawing (Figure 13) of the OH-6A, Figure 12 contains a summary of the characteristics and limitations of this helicopter model. The OH-6A's instrumented for the SEA recording program had two major configurations: the "lead ship" and the "wing ship," the former identified by a pilot and two gunners each with an M-60 machine gun, and the latter by a pilot and one gunner with an XM-27 minigun mounted on the left side.



Characteristics		Limitations	
rotor diameter	26 ft 4 in.	normal rated power	214.5 hp
rotor solidity	0.0544	design power	252.5 hp
engine (Allison)	T63-A-5A	usable power (normal rated)	214.5 hp
mission gross wt.	2163 lb	max. allowable airspeed	125 kn
alternate gross wt.	2400 lb	100% rotor rpm	469 rpm
empty weight (avg)	1163 lb	transmission torque limits	90 psi(10 sec), 100 psi (3 sec)
		g limits @ 2400 lb	+2.54g, -0.5g
		g limits @ 2163 lb	+2.82g, -0.5g

Figure 12. Photograph of OH-6A Helicopter.

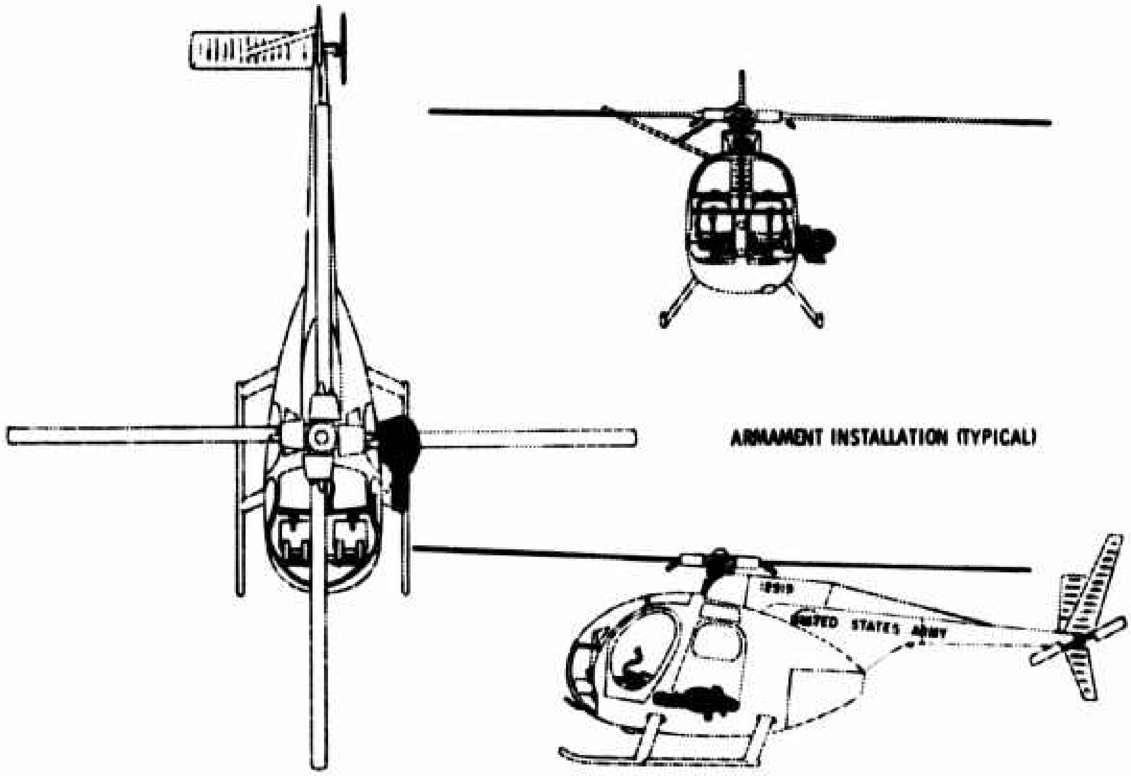
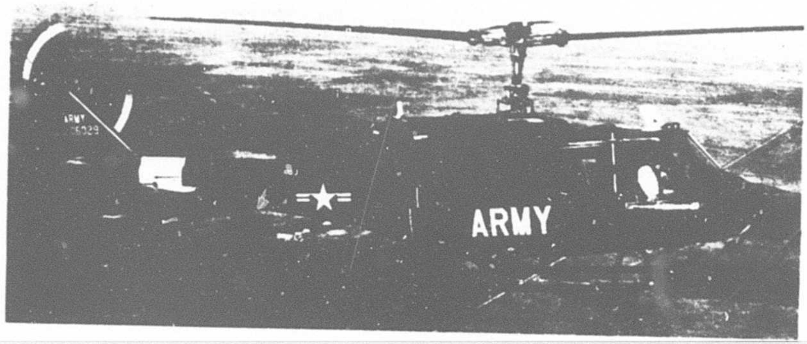


Figure 13. Multiview Drawing of OH-6A Helicopter.

1.5.4 Bell UH-1H Representing the Assault and Utility Class Helicopters

The UH-1H "Huey" is an all-metal, single-engine helicopter. A single, two-bladed, semirigid teetering main rotor provides lift, and a two-bladed, semirigid, delta-hinged tail rotor provides antitorque and directional control. The helicopter was designed for both combat support and combat assault missions. Figures 14 and 15 present a photo and a multiview drawing of this helicopter model. Additionally, Figure 14 contains basic data identifying some of the aircraft operational characteristics and limitations.



Characteristics	
rotor diameter	48 ft
rotor solidity	0.0464
engine	Lycoming T-53-L-13
design max. gross wt.	9500 lb
empty weight (avg)	4920 lb

Limitations	
normal rated power	1250 shp
military rated power	1400 shp
usable power (transmission limit)	1100 hp
100% rotor speed	324 rpm
max. airspeed	120 kn

Figure 14. Photograph of UH-1H Helicopter.

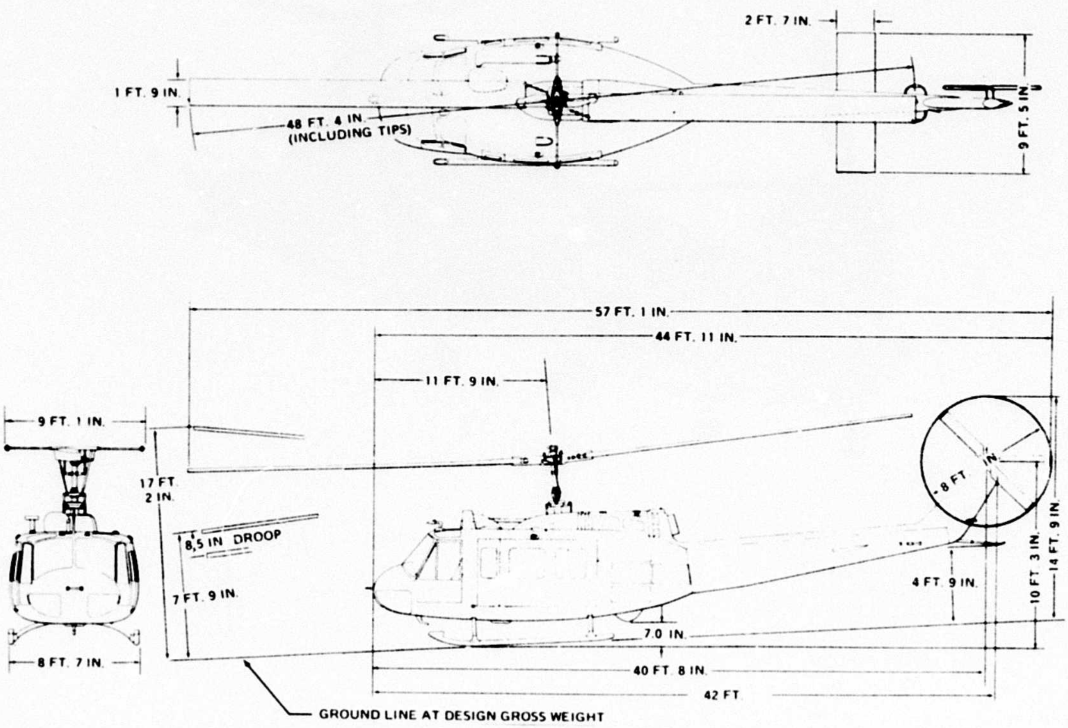


Figure 15. Multiview Drawing of UH-1H Helicopter.

1.3.5 Boeing CH-47A Representing the Transport Class Helicopters

The CH-47A "Chinook" helicopter is a twin-turbine-engine, tandem-rotor medium-lift aircraft designed for the transportation of cargo (internal or external) and weapons during day and night and visual and instrument conditions. Each aircraft is powered by two shaft-turbine engines mounted on the aft fuselage. The engines simultaneously drive two tandem 3-bladed rotors through a combining transmission drive shafting and reduction transmission. Fuel is carried in a pod on each side of the fuselage. The helicopter is equipped with four nonretractable landing gear. Figures 16 and 17 present a photo and multiview drawing of this helicopter model. Additionally, Figure 16 contains basic data identifying some of the aircraft operational characteristics and limitations.

Characteristics		Limitations	
rotor diameter	59 ft	normal rated power	2200 shp
engines (two)	T55-1-7B	military rated power	2650 shp
no. blades per rotor	3	100% rotor rpm	230 rpm
design gross wt.	28,550 lb	g limits @ 28,550 lb	+2.67g, -.5g
alternate gross wt.	33,000 lb	max. airspeed	130 kn
empty weight (avg)			

Figure 16. Photograph of CH-47A Helicopter.

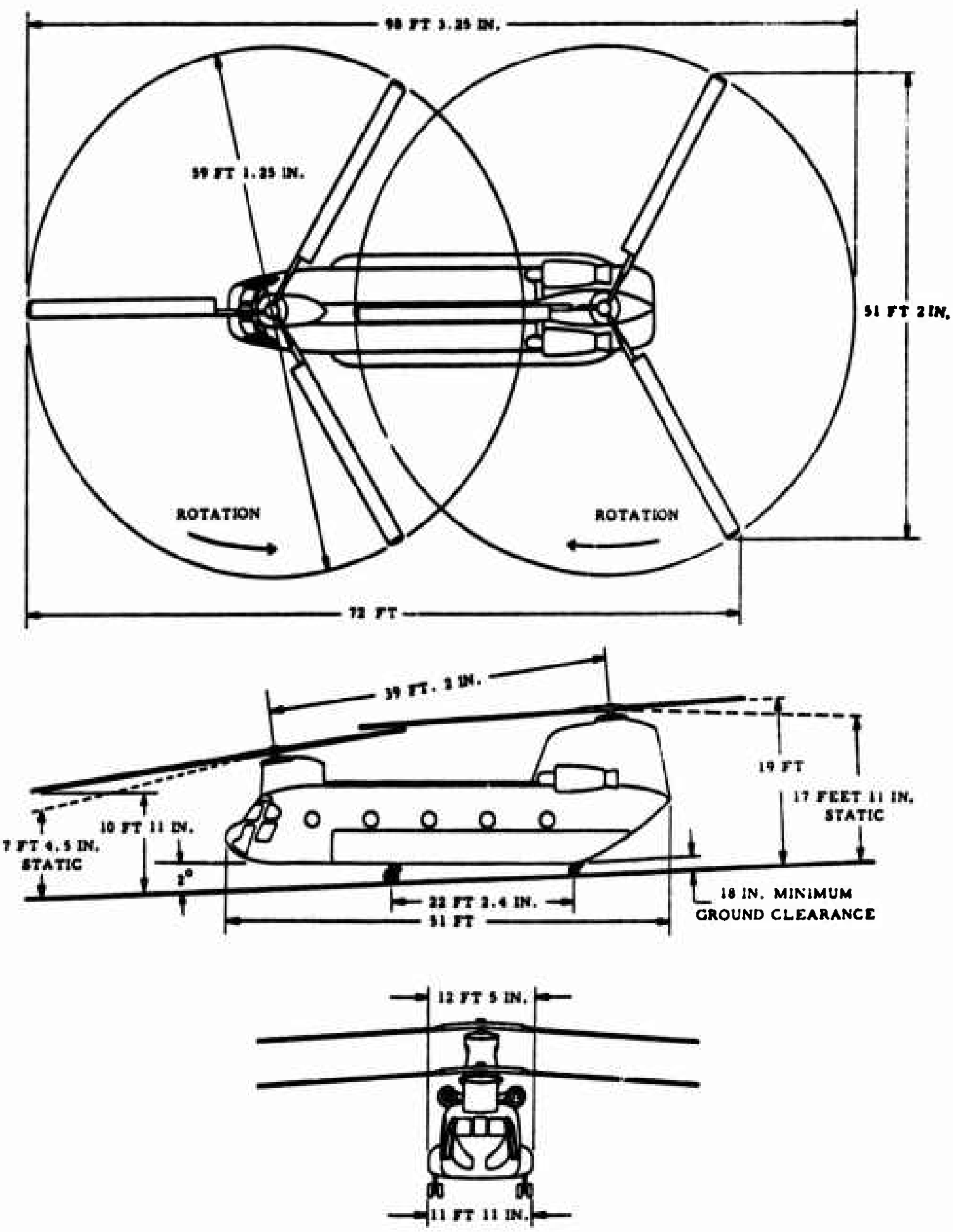


Figure 17. Multiview Drawing of CH-47A Helicopter.

2. DATA PRESENTATION AND ANALYSIS

2.1 INTRODUCTION

The data presentation and analysis consists of the following: (1) the operational mission profile for each of the six helicopter class-model categories listed in Table 1, (2) the comparison of the manufacturer's design and the Navy AR-56 mission profiles with the operational mission profiles as adapted to the formats of the other profiles and including the ground time, (3) the comparison of the manufacturer's design and the Navy AR-56 mission profiles with the operational mission profiles as adapted to the formats of the other profiles but excluding the ground time, and (4) the design mission profiles for future helicopters in each of the six helicopter classes. Each of the above-mentioned presentations is in the order of the helicopter class listing in Table 1.

On the basis of immediate significance and practicality in the data analysis, each operational mission profile consists primarily of the frequency of flight conditions and the percentage of total mission time spent in performing them with a breakdown by mission segment. In addition, each profile includes (1) the average duration of maneuver normal load factors (n_z's) in n_z ranges with a breakdown by mission segment and flight condition, (2) the frequency of maneuver n_z's in n_z versus coincident gross weight and c.g. ranges and the percentage of total mission time spent in all coincident gross weight and c.g. ranges, and (3) the frequency of landing impact Δn_z's after landings from both descent and hover and of taxi Δn_z's in Δn_z versus gross weight ranges.

The operational mission profiles include ground operations because of their appreciable contribution to structural fatigue and mean-time-between-overhaul (MTBO) as well as to the operational usage spectrum. However, since neither the manufacturer's design nor the Navy AR-56 mission profiles include steady-state ground operations, the mission profile comparisons are twofold: the first with the operational mission profiles including ground time and the second with these profiles excluding the ground time.

Preparatory to making the two sets of comparisons, it was assumed that the "percent occurrence" as used by Hughes and Boeing, the "percent aircraft time" as used by Sikorsky, the "percent time" as used by Bell, and the "percent service life" as used by the Navy all denote the "percentage of total in-flight time spent in the respective mission segments and flight conditions." Consequently, in adapting the operational mission profiles for these comparisons, specifically the tables of operational usage spectra representing both the

frequency of flight conditions and the percentage of time in performing them, the percentages of time were changed to the formats of the manufacturers' and Navy AR-56 data and subsequently used for the comparisons. Only as necessary were the flight condition frequencies included in the modified tables. Such frequencies, expressed as the number of occurrences per 100 hours of flight, are indicated by the figures enclosed in parentheses.

2.2 OPERATIONAL MISSION PROFILES

2.2.1 Attack - AH-1G Helicopter

The operational usage spectrum for the attack (AH-1G) helicopter is summarized in Table 2 which represents 16.2 hours of operational usage data. In this table, the largest percentages of flight time are in the level flight, ground operation, descent, and ascent mission segments and generally in the steady-state, unknown, and pushover flight conditions.

Level flight time is moderately long, but the high percentages of ascent, descent, and maneuver time indicate that the helicopters were in a hostile environment where many evasive and strafing type maneuvers were performed. This extensive maneuvering is also indicated in Tables 3 and 4. Table 3 lists the average duration of n_z's beyond threshold for any flight condition in which a vertical acceleration peak occurred, and Table 4 lists the n_z frequencies in n_z versus gross weight and c.g. ranges with the percentage of flight time for those coincident ranges. As apparent from these two tables, the highest n_z levels were reached and the longest n_z durations were experienced in the dive pull-out and unknown conditions, and the greatest n_z frequencies occurred in the 8000- and 9000-lb ranges (in all references to parameter ranges, only the lower limit of each range is cited; therefore, in this instance, "8000" represents the 8000- to 9000-lb range, and "9000" represents the range of 9,000 lb and above) with the c.g. at the 193 position for both weight ranges.

Landing impact and taxi Δn_z's are summarized in Figure 18 and Tables 5 and 6. As indicated in Figure 18 and detailed in Table 5, landing impact peaks from hover occurred approximately 6 times more often than those from descent. For the Δn_z's due to ground handling and taxi, Table 6 shows that the positive and negative Δn_z's were equally distributed. Since these Δn_z's occurred within about 30 seconds after landing as well as before takeoff, and since the AH-1G is not equipped to taxi for long distances, they were probably related more to landing impacts than to taxi operations.

TABLE 2. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR AH-1G ATTACK MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				25.79
Rotor Start	111	-	-	
Steady State, Minimum	196	116	1.85	
Steady State, Average	196	225	3.58	
Steady State, Maximum	196	682	10.85	
Transient	643	598	9.51	
Rotor Stop	111	-	-	
Hover:				3.55
Steady State, Minimum	103	21	.33	
Steady State, Average	103	61	.97	
Steady State, Maximum	103	89	1.41	
Takeoff	167	42	.67	
Collective Pushover	12	3	.05	
Collective Pull-Up	12	3	.05	
Touchdown	167	-	-	
Longitudinal Reversal	19	1	.02	
Initiation of Ascent	25	3	.05	
Ascent:				14.51
Steady State, Minimum	192	67	1.07	
Steady State, Average	192	180	2.86	
Steady State, Maximum	192	499	7.94	
Takeoff	6	2	.03	
Collective Pushover	130	22	.35	
Collective Pull-Up	25	2	.03	
Cyclic Pushover	12	3	.05	
Cyclic Pull-Up	6	2	.03	
Initiation of Ascent	43	8	.13	
Mission Segment Change Without Maneuver	334	-	-	
Dive Pull-Out	167	58	.92	
Unknown Condition, Minimum	58	9	.14	
Unknown Condition, Average	58	20	.32	
Unknown Condition, Maximum	58	40	.64	
Level Flight:				35.86
Steady State, Minimum	239	191	3.04	
Steady State, Average	239	468	7.46	
Steady State, Maximum	239	1459	23.21	
Collective Pushover	186	30	.47	
Collective Pull-Up	130	26	.41	
Cyclic Pushover	12	3	.05	
Cyclic Pull-Up	12	3	.05	
Mission Segment Change Without Maneuver	278	-	-	
Unknown Condition, Minimum	68	12	.19	
Unknown Condition, Average	68	18	.28	
Unknown Condition, Maximum	68	44	.70	

TABLE 2. (Concluded)

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time
Descent:			8.23
Steady State, Minimum	122	26	.41
Steady State, Average	122	72	1.15
Steady State, Maximum	122	304	4.84
Collective Pushover	56	15	.24
Collective Pull-Up	93	23	.37
Flare	19	11	.17
Touchdown	6	-	-
Cyclic Pushover	19	5	.08
Mission Segment Change Without Maneuver	136	-	-
Dive	80	32	.51
Unknown Condition, Minimum	25	7	.11
Unknown Condition, Maximum	25	22	.35
Autorotation:			.05
Steady State	6	1	.02
Collective Pushover	6	0	.00
Collective Pull-Up	6	0	.00
Power to Autorotation	6	1	.02
Autorotation to Power	6	1	.02
IGE Maneuvers:			5.36
Steady State, Minimum	76	25	.40
Steady State, Average	76	50	.79
Steady State, Maximum	76	138	2.20
Collective Pushover	31	7	.11
Collective Pull-Up	37	3	.04
Cyclic Pull-Up	6	1	.02
Mission Segment Change Without Maneuver	12		-
Unknown Condition	192	113	1.80
Full Power Climb:			.49
Steady State	50	19	.30
Collective Pushover	6	2	.03
Initiation of Ascent	37	10	.16
Mission Segment Change Without Maneuver	6	-	-
Partial Power Descent			6.16
Steady State, Minimum	66	52	.83
Steady State, Average	66	73	1.16
Steady State, Maximum	66	120	1.92
Collective Pushover	124	35	.55
Collective Pull-Up	93	21	.33
Flare	99	78	1.24
Mission Segment Change Without Maneuver	12	-	-
Dive	6	2	.03
Unknown Condition	25	6	.10

TABLE 3. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR AH-1G ATTACK MISSION

Mission Segment	Flight Condition	0.5	0.6	0.7	0.8	1.2	1.3	1.4	1.5	1.6	1.7	1.8
						n_z Level						
						.09						
Ascent	Steady State			1.2		.4						
	Collective Pushover						6.0	7.2				
	Collective Pull-Up							6.6				
				1.8								
	Cyclic Pull-Up					0.0	8.7	10.0	11.3	11.4	11.1	10.5
	Dive Pull-Out			0.0		6.3	6.4	12.4	15.6			
	Unknown											
				0.0		0.0						
Level Flight	Steady State						7.2					
	Takeoff					0.0						
	Collective Pushover					1.5	9.0					
	Collective Pull-Up						6.9					
	Cyclic Pull-Up			1.8		3.9	8.3	10.1	9.0	10.8		
	Unknown											
				0.0		.11						
Descent	Steady State					4.5	8.4	15.0				
	Collective Pushover					.45						
	Collective Pull-Up			1.8		0.0						
	Cyclic Pushover			2.4		0.0						
	Dive			1.2		5.4	6.8	10.8				
	Unknown											
				.6								
Autorotation	Collective Pushover						1.2					
	Collective Pull-Up											
	Power to Autorotation		4.2									
						0.0						
IGE Maneuver	Steady State					3.0						
	Collective Pushover					7.0	12.4	15.6				
	Unknown											
						0.0						
Partial Power Descent	Steady State			0.0								
	Collective Pushover					6.3	1.2					
	Collective Pull-Up							9.4	27.0			
	Unknown											

TABLE 4. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR AH-1G ATTACK MISSION

Gross Weight (lb)	Center of Gravity	Percent Time	.5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7	1.8
						n_z Level						
7,000	192	1.75										
8,000	191	.09										
	192	36.43				4	2					
	193	21.16			5	72	20	10	9	1		1
	194	.006										
9,000	193	40.56		1	10	42	10	5		1	1	1

There were 30 ground-air-ground (GAG) cycles but only 18 rotor start-stop cycles observed in the data sample. This difference indicates that when the aircraft landed the power remained on to permit immediate takeoff in the event of enemy fire and that while the aircraft awaited enemy engagement it did not hover but rather rested on the ground.

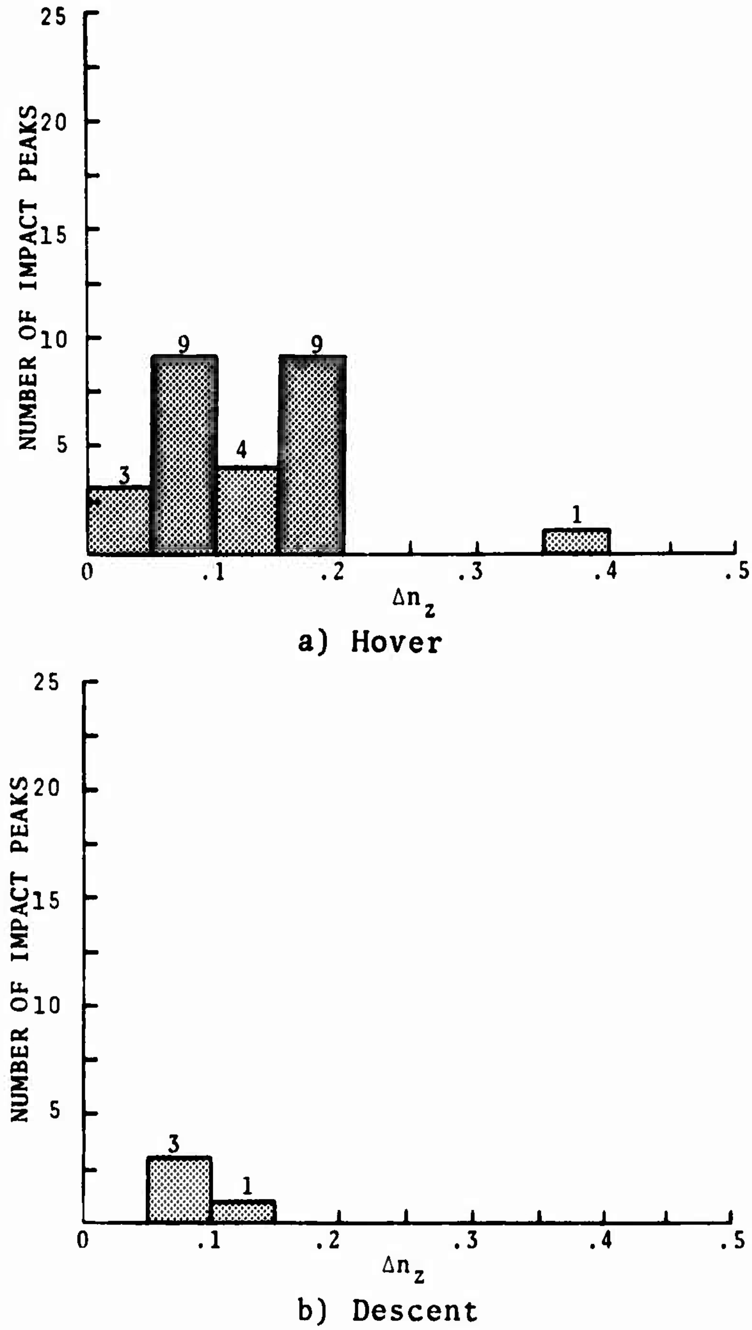


Figure 18. AH-1G Landing Impact Peaks.

TABLE 5. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR AH-1G ATTACK MISSION

a) HOVER

WEIGHT RANGE	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
						Δn_z						
6000												
7000		1										1
8000	1	6	3	4								14
9000	2	2	1	5				1				11
TOTAL	3	9	4	9				1				26

b) DESCENT

WEIGHT RANGE	.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
						Δn_z						
6000												
7000		1										1
8000		2	1									3
9000												
TOTAL		3	1									4

TABLE 6. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES FOR AH-1G ATTACK MISSION

WEIGHT RANGE	-.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
								Δn_z								
6000																
7000									1							1
8000						2	21		19	2						44
9000						3	14		13	5						35
TOTAL						5	35		33	7						80

2.2.2 Crane - CH-54A Helicopter

The operational usage spectrum for the crane (CH-54A) helicopter is summarized in Table 7 which represents 12.2 hours of operational usage data. In this table, the largest percentages of flight time are in the ascent, level flight, and descent mission segments, indicating that the aircraft made frequent cargo pickups and deliveries with relatively short distances from the pickup area to the delivery area. As indicated in Table 9, the aircraft flew at low gross weights most of the time; thus the distance between cargo pickup and cargo drop was short. In addition, since about 84 percent of the flight time was in steady-state operation and only some 12 percent in maneuvers, the n_z's experienced by this aircraft were few and of low magnitude, as indicated in Tables 8 and 9. These tables also indicate that the n_z's occurred mostly during cargo drops and collective pull-ups. Consequently, the n_z's were probably caused by the collective input to reduce the power required to hover immediately after a cargo drop. In addition, the n_z's generated by the pull-ups were most likely a result of transitions from level flight to ascent and from descent to level flight.

Table 10 and Figure 19 indicate that the landing impact Δn_z's from hover and descent were generally equally severe and numerous. Although landings from hover occurred approximately 1.7 times more often than those from descent (seven landings from hover versus four from descent in the data sample), the landings from descent generally produced twice as many impact Δn_z's at each landing than the landings from hover.

In marked contrast to Table 10 with its total of 18 for the combined landing impact Δn_z's from hover and descent, Table 11 lists 353 Δn_z's experienced during taxi. Of the latter Δn_z's, 67 percent occurred in the 21,000-pound range which is representative of the normal landing gross weight. Therefore, as expected, most of the taxi Δn_z's occurred after landing and likely in response to landing.

There were 19 GAG cycles but only 4 rotor start-stop cycles observed in the data sample. This relatively low number of rotor start-stop cycles indicates that the aircraft did not usually shut down after landing, probably because of its operation in hostile areas with the need to be prepared for immediate takeoff.

TABLE 7. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR CH-54A CRANE MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				9.38
Rotor Start	27	-	-	
Steady State, Minimum	62	16	.29	
Steady State, Average	62	53	.97	
Steady State, Maximum	62	268	4.92	
Transient	100	75	1.38	
Rotor Stop	27	-	-	
Ground Taxi	113	99	1.82	
Hover:				5.49
Steady State, Minimum	108	28	.51	
Steady State, Average	108	52	.96	
Steady State, Maximum	108	116	2.13	
Takeoff	53	15	.28	
Collective Pushover	20	4	.07	
Collective Pull-Up	27	5	.09	
Touchdown	80	-	-	
Longitudinal Reversal	13	1	.02	
Initiation of Ascent	120	30	.55	
Cargo Pickup	106	42	.77	
Cargo Drop	47	6	.11	
Ascent:				27.32
Steady State, Minimum	182	125	2.30	
Steady State, Average	182	354	6.50	
Steady State, Maximum	182	838	15.39	
Takeoff	67	43	.79	
Collective Pushover	200	64	1.18	
Collective Pull-Up	73	18	.33	
Cyclic Pull-Up	7	2	.04	
Longitudinal Reversal	13	-	-	
Initiation of Ascent	160	43	.79	
Mission Segment Change Without Maneuver	273	-	-	
Level Flight:				29.52
Steady State, Minimum	120	171	3.14	
Steady State, Average	120	344	6.32	
Steady State, Maximum	120	1023	18.79	
Collective Pushover	120	48	.88	
Collective Pull-Up	80	20	.37	
Mission Segment Change Without Maneuver	193	-	-	
Unknown Condition	7	1	.02	
Descent:				16.79
Steady State, Minimum	171	68	1.25	
Steady State, Average	171	189	3.47	
Steady State, Maximum	171	483	8.87	
Collective Pushover	180	47	.86	
Collective Pull-Up	206	62	1.14	
Flare	106	55	1.01	
Touchdown	33	-	-	
Cyclic Pull-Up	13	3	.06	

TABLE 7. (Concluded)

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Mission Segment Change Without Maneuver	80	-	-	
Cargo Drop	67	7	.13	
Full Power Climb:				.20
Steady State	73	10	.18	
Initiation of Ascent	7	1	.02	
Partial Power Descent:				11.30
Steady State, Minimum	135	42	.77	
Steady State, Average	135	107	1.97	
Steady State, Maximum	135	307	5.64	
Collective Pushover	219	64	1.18	
Collective Pull-Up	153	40	.73	
Flare	126	53	.97	
Touchdown	13	-	-	
Cyclic Pull-Up	7	2	.04	

TABLE 8. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR CH-54A CRANE MISSION

		n_z Level										
Mission Segment	Flight Condition	0.4	0.5	0.6	0.7	0.8	1.2	1.3	1.4	1.5	1.6	1.7
Hover	Cargo Drop				1.5							
Ascent	Steady State						0.0					
	Collective Pull-Up						.36					
Level Flight	Steady State						0.0					
	Collective Pushover						0.0					
Descent	Collective Pull-Up						.22					
	Cargo Drop				0.5		.22					
Partial Power Descent	Collective Pull-Up						.53					

TABLE 9. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR CH-54A CRANE MISSION

Gross Weight (lb)	Center of Gravity	Percent Time	n_z Level .5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7	1.8
23,000	339	.031										
	340	2.98										
	341	8.14				2						
	342	.813			1	1						
	343	.002										
25,000	338	.164										
	339	3.63										
	340	14.07										
	341	9.72				4						
	342	.951										
	343	.242										
27,000	341	16.50			1							
29,000	340	2.50										
31,000	336	.020										
	337	.49										
	338	2.92										
	339	4.29										
	340	1.56										
	341	.141										
	342	.003										
33,000	337	.024										
	338	2.12										
	339	7.17										
	340	1.16										
	341	.072										
36,000	339	3.10				1						
37,000	339	3.46										
38,000	336	.001										
	337	.478										
	338	3.98			1							
	339	1.43										
	340	.016										
39,000	336	.049										
	337	1.56										
	338	3.22										
	339	.074										
40,000	338	3.00										

TABLE 10. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR CH-54A CRANE MISSION

a) HOVER

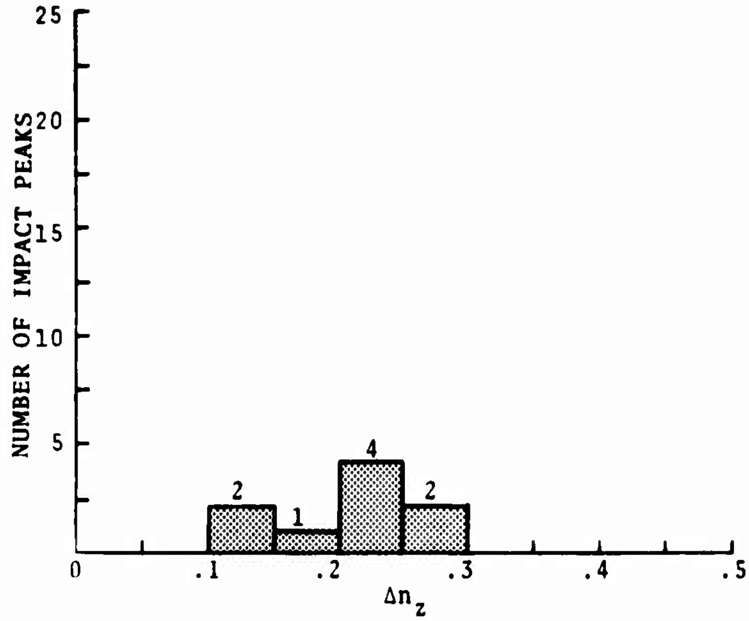
WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less			1	1	2	2						6
21000			1		2							3
23000												
25000												
TOTAL			2	1	4	2						[illegible]

b) DESCENT

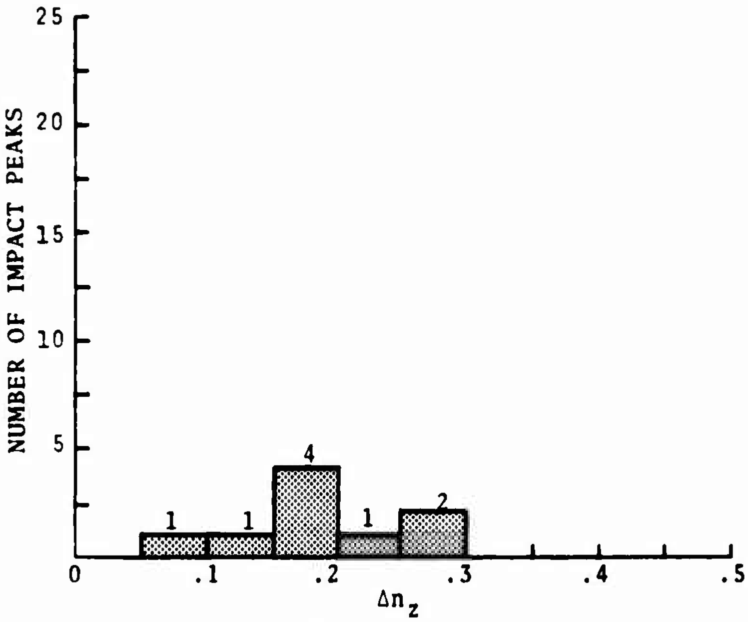
WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less												
21000		1	1	1		2						5
23000				3	1							4
25000												
TOTAL		1	1	4	1	2						[illegible]

TABLE 11. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGE FOR CH-54A CRANE MISSION

WEIGHT RANGE	Δn_z .40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
Less			1	2	1	7	25		31	3	3	2				
21000				1	2	12	58		139	17	6	1				236
23000				1		1	10		23	3	4					42
25000																
TOTAL			1	4	3	20	93		193	23	13	3				[illegible]



a) Hover



b) Descent

Figure 19. CH-54A Landing Impact Peaks.

2.2.3 Observation - OH-6A Helicopter

The spectrum of flight condition frequency for the observation (OH-6A) helicopter is summarized in Table 12 which represents 14.1 hours of operational usage data. According to this table, 25 percent of the flight time was spent in performing maneuvers. Of this time, 80 percent was in the IGE maneuver where a helicopter flies in a nap-of-the-earth (NOE) manner. The small percentages of time in ascent and descent indicate that the helicopter flew at very low altitudes and therefore would have experienced numerous n_z's due to the nap-of-the-earth maneuvering, as is evident in Table 13.

In Table 13 for the maneuver durations beyond the n_z threshold, most of the distribution at the higher n_z levels is in the collective pull-up and unknown conditions of the IGE maneuver mission segment. Since the durations of the unknown conditions (assumed to be mainly turns) were longer than normal and usually reached a higher n_z level, the helicopter probably made many steeply banked turns at low altitude.

In Table 14 for the frequency of maneuver n_z's in n_z versus gross weight and c.g. ranges, all n_z's are in the 2200- and 2400-pound gross weight ranges and at c.g. stations 99 and 100 where about 65 percent of the flight time was spent. This distribution indicates that the c.g. position varied little with fuel burnoff and ammunition firing and that the flights were of short duration because of the gross weight constancy. The flights averaged 68 minutes, of which 21 minutes (or 30.6 percent) was in the IGE maneuver where the largest n_z's occurred.

As indicated in Table 15 and Figure 20, the landing impact Δn_z's were mild and their occurrences were fairly equally distributed in the landings from hover and descent. Like Table 15, Table 16 distributes the frequency of taxi Δn_z's in Δn_z versus gross weight ranges. Since the OH-6A is not equipped for taxiing, most of the taxi Δn_z's would be related to landing impact and therefore occurred after landing. Although the landing impact and taxi Δn_z's were not severe, they indicate the unsteadiness of a touchdown. Also, most of the touchdowns were followed by periods of ground idle, as evidenced by the fact that there were 32 GAG cycles but only 11 rotor start-stop cycles observed in the data sample.

TABLE 12. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR OH-6A OBSERVATION MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				23.53
Rotor Start	78	-	-	
Steady State, Minimum	176	84	1.42	
Steady State, Average	176	360	6.07	
Steady State, Maximum	176	755	12.72	
Transient	505	192	3.24	
Rotor Stop	78	-	-	
Ground Taxi	21	5	.08	
Hover:				3.55
Steady State, Minimum	104	24	.40	
Steady State, Average	104	38	.64	
Steady State, Maximum	104	108	1.82	
Takeoff	157	20	.34	
Collective Pushover	43	3	.05	
Collective Pull-Up	50	5	.08	
Touchdown	128	-	-	
Cyclic Pushover	14	4	.07	
Cyclic Pull-Up	7	1	.02	
Longitudinal Reversal	28	2	.03	
Initiation of Ascent	14	6	.10	
Ascent:				8.14
Steady State, Minimum	133	33	.56	
Steady State, Average	133	64	1.08	
Steady State, Maximum	133	288	4.85	
Takeoff	43	6	.10	
Collective Pushover	164	28	.47	
Collective Pull-Up	142	33	.56	
Cyclic Pushover	14	4	.07	
Cyclic Pull-Up	7	1	.02	
Initiation of Ascent	21	8	.13	
Mission Segment Change Without Maneuver	100	-	-	
Unknown Condition	39	4	.07	
Unknown Condition	39	14	.23	
Level Flight:				22.43
Steady State, Minimum	130	72	1.21	
Steady State, Average	130	267	4.50	
Steady State, Maximum	130	917	15.45	
Takeoff	7	1	.02	
Collective Pushover	199	32	.54	
Collective Pull-Up	135	27	.46	
Cyclic Pushover	7	3	.05	
Mission Segment Change Without Maneuver	78	-	-	
Unknown Condition	25	2	.03	
Unknown Condition	25	10	.17	

TABLE 12. (Continued)

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Descent:				8.72
Steady State, Minimum	142	23	.39	
Steady State, Average	142	68	1.15	
Steady State, Maximum	142	276	4.65	
Collective Pushover	292	50	.84	
Collective Pull-Up	249	40	.67	
Flare	57	19	.32	
Touchdown	78	-	-	
Mission Segment Change Without Maneuver	43	-	-	
Unknown Condition	52	8	.13	
Unknown Condition	52	13	.22	
Unknown Condition	52	21	.35	
IGE Maneuvers:				30.55
Steady State, Minimum	797	88	1.48	
Steady State, Average	797	151	2.54	
Steady State, Maximum	797	399	6.72	
Takeoff	21	3	.05	
Collective Pushover	2477	272	4.58	
Collective Pull-Up	2804	365	6.15	
Flare	14	8	.13	
Touchdown	14	-	-	
Cyclic Pushover	199	32	.54	
Cyclic Pull-Up	71	4	.07	
Longitudinal Reversal	149	12	.20	
Initiation of Ascent	7	2	.03	
Mission Segment Change Without Maneuver	21	-	-	
Unknown Condition, Minimum	498	80	1.35	
Unknown Condition, Average	498	149	2.51	
Unknown Condition, Maximum	498	249	4.20	
Takeoff Power Climb:				.05
Collective Pushover	7	0	.00	
Collective Pull-Up	7	0	.00	
Initiation of Ascent	14	3	.05	
Full Power Climb:				2.16
Steady State, Minimum	57	16	.27	
Steady State, Maximum	57	87	1.47	
Collective Pushover	36	7	.12	
Collective Pull-Up	7	1	.02	
Cyclic Pushover	7	0	.00	
Longitudinal Reversal	7	1	.02	
Initiation of Ascent	36	11	.19	
Mission Segment Change Without Maneuver	14	-	-	
Unknown Condition	28	4	.07	

TABLE 12. (Concluded)

Mission Segment Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time
Partial Power Descent:			.87
Steady State	100	11	.19
Collective Pushover	71	10	.17
Collective Pull-Up	85	9	.15
Flare	36	11	.19
Longitudinal Reversal	7	1	.02
Mission Segment Change Without Maneuver	7	-	-
Unknown Condition	28	9	.15

TABLE 13. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR OH-6A OBSERVATION MISSION

Mission Segment	Flight Condition	n_z Level 0.4	0.5	0.6	0.7	0.8	1.2	1.3	1.4	1.5	1.6	1.7
Ascent	Steady State						.00					
	Collective Pushover			8.22			.04					
	Collective Pull-Up						1.56					
	Unknown Condition						.95	1.88		17.52		
Level Flight	Steady State						.00					
	Collective Pushover			2.18	.36							
	Collective Pull-Up						.30	.96				
	Unknown Condition						1.45	2.82				
Descent	Steady State						.00					
	Collective Pushover						.00					
	Collective Pull-Up				.00		1.02	3.78	1.38	8.76		
	Unknown						.87	3.17	3.36	7.58	24.96	
IGE Maneuver	Steady State				.00		.19	.32				
	Collective Pushover		1.14		.29		.22	.00				
	Collective Pull-Up				.78		1.08	3.91	7.03	10.40	6.63	
	Cyclic Pushover		3.66	2.25	.49		.00					
	Cyclic Pull-Up						.00		3.72	2.64		
	Initiation of Ascent						.00					
	Unknown Condition				.78		1.07	3.18	4.81	10.07	9.91	12.47
Full Power Climb	Steady State						.00					
	Unknown Condition						1.22				3.54	
Partial Power Descent	Steady State						2.02					
	Collective Pull-Up						.00	2.82				
	Unknown Condition						.90		6.07			

TABLE 14. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR OH-6A OBSERVATION MISSION

Gross Weight(lb)	Center of Gravity	Percent Time	n_z Level .5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7
2000	96	.044									
	97	.393									
	98	1.53									
	99	2.14									
	100	1.09									
	101	.203									
	102	.014									
2200	96	.286									
	97	3.78									
	98	17.59									
	99	25.74			15	155	79	24	26	15	4
	100	11.78		1	2	54	30	2	7	2	
	101	1.75									
	102	.085									
2400	97	.199									
	98	4.08									
	99	15.63	2	3	5	41	13	7	1	3	
	100	11.97			3	44	22	9	2	2	
	101	1.76									
	102	.047									

TABLE 15. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR OH-6A OBSERVATION MISSION

a) HOVER

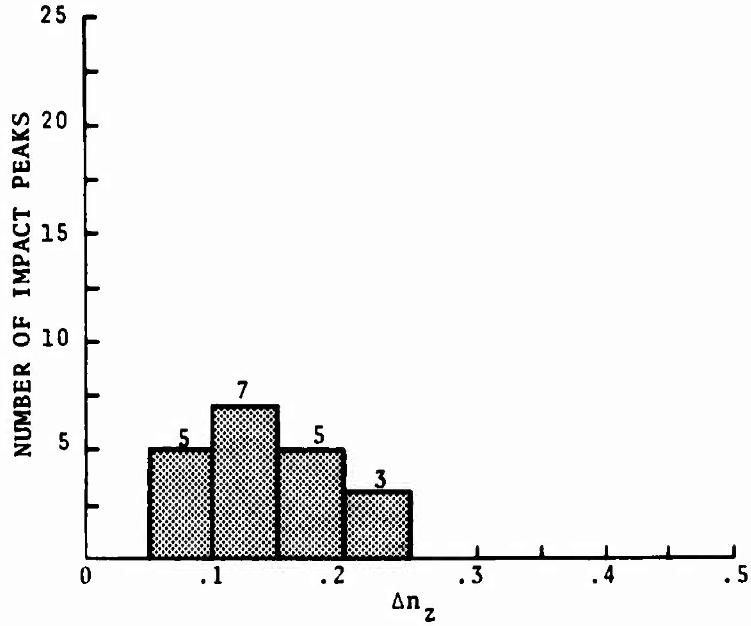
WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less 2000		1										1
2200			5	4	2							11
2400		4	2	1	1							8
2600												
TOTAL		5	7	5	3							20

b) DESCENT

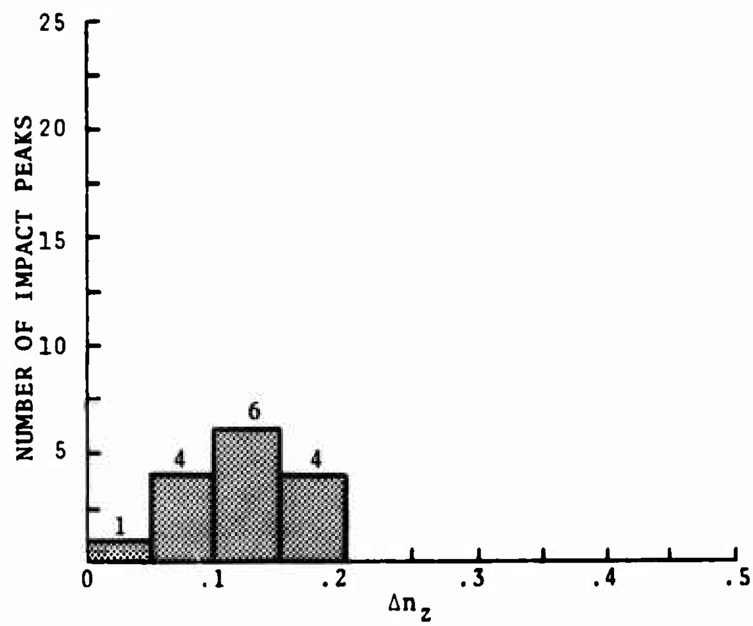
WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less 2000			1									1
2200	1	3	4	4								12
2400		1	1									2
2600												
TOTAL	1	4	6	4								15

TABLE 16. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES FOR OH-6A OBSERVATION MISSION

WEIGHT RANGE	Δn_z -.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
Less 2000							1		4							5
2200					1	9	28		21	4	3					66
2400						4	17		13		1					35
2600																
TOTAL					1	13	46		38	4	4					106



a) Hover



b) Descent

Figure 20. OH-6A Landing Impact Peaks.

2.2.4 Assault - UH-1H Helicopter

The spectrum of flight condition frequency for the assault (UH-1H) helicopter is summarized in Table 17 which represents 6.8 of the 22.1 hours in the UH-1H data sample. The 6.8 hours were selected since they were recorded in assault, command and control, and ELSA types of missions which are generally representative of a utility tactical transport aircraft system (UTTAS) helicopter in the assault role. As indicated in this table, the smaller than expected amount of flight time in maneuvers (6.6 percent) may be attributed to the fact that since UH-1H pilots are qualified primarily for utility missions, they tend to fly assault missions conservatively. Consequently, as indicated in Tables 18 and 19, the number and duration of maneuver n_z's were small and generally short. As seen in Table 18, the unknown conditions, which were likely turns, had the longest durations and the highest levels of the recorded n_z's.

Although Table 19 indicates that the aircraft flew in the lower gross weight ranges where more power is normally available to perform severe maneuvers, the warm climate would have reduced the power so that the aircraft flew near the torque pressure limits as indicated in USAAMRDL Technical Report 73-105[6] and therefore could not perform severe maneuvers.

As indicated in Table 20 and Figure 21, the landing impact peaks from hover occurred 18 times more frequently than those from descent. The landing impact Δn_z's were not very severe in the landings from either hover or descent.

As shown in Table 17, 28.5 percent of the flight time was spent in the ground operation mission segment where the aircraft operated at ground idle instead of being shut down because of the aircraft's lack of an auxiliary power unit (APU). That the engine remained running after landings is evidenced by the fact that there were 19 GAG cycles but only 6 rotor start-stop cycles observed in the data sample.

Table 21 shows that both the frequency and the magnitude of the taxi Δn_z's were small. Since the UH-1H is not equipped to taxi long, most of these Δn_z's were likely related to the landing impact Δn_z's.

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[6] Johnson, Raymond B., and Cox, Terry L., HELICOPTER DRIVE SYSTEM LOAD ANALYSIS, Technology Incorporated, Dayton, Ohio; USAAMRDL Technical Report 73-105, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, January 1974, AD 775858.

TABLE 17. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR UH-1H ASSAULT MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				27.51
Rotor Start	89	-	-	
Steady State, Minimum	277	89	1.54	
Steady State, Average	277	373	6.44	
Steady State, Maximum	277	915	15.80	
Transient	770	216	3.73	
Rotor Stop	89	-	-	
Hover:				5.54
Steady State, Minimum	153	38	.66	
Steady State, Average	153	61	1.05	
Steady State, Maximum	153	147	2.54	
Takeoff	252	48	.83	
Collective Pushover	89	7	.12	
Collective Pull-Up	119	9	.16	
Touchdown	267	-	-	
Initiation of Ascent	119	11	.18	
Mission Segment Change Without Maneuver	74	-	-	
Ascent:				15.48
Steady State, Minimum	133	89	1.54	
Steady State, Average	133	225	3.89	
Steady State, Maximum	133	535	9.23	
Takeoff	30	4	.07	
Collective Pushover	267	37	.64	
Collective Pull-Up	44	5	.09	
Initiation of Ascent	15	1	.02	
Mission Segment Change Without Maneuver	119	-	-	
Level Flight:				33.93
Steady State, Minimum	94	105	1.81	
Steady State, Average	94	340	5.87	
Steady State, Maximum	94	1497	25.86	
Collective Pushover	133	20	.35	
Collective Pull-Up	30	3	.05	
Mission Segment Change Without Maneuver	104	-	-	
Descent:				10.55
Steady State, Minimum	138	37	.64	
Steady State, Average	138	105	1.81	
Steady State, Maximum	138	383	6.61	
Collective Pushover	193	25	.43	
Collective Pull-Up	119	18	.31	
Flare	119	36	.62	
Touchdown	15	-	-	
Mission Segment Change Without Maneuver	15	-	-	
Unknown Condition	30	7	.12	

TABLE 17. (Concluded)

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Takeoff Power Climb:				.07
Steady State	15	3	.05	
Collective Pushover	15	1	.02	
Full Power Climb:				1.40
Steady State	119	72	1.24	
Unknown Condition	30	9	.16	
Partial Power Descent:				5.51
Steady State, Minimum	222	36	.62	
Steady State, Maximum	222	144	2.49	
Collective Pushover	296	50	.86	
Collective Pull-Up	104	11	.19	
Flare	104	48	.83	
Unknown Condition	74	30	.52	

TABLE 18. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR UH-1H ASSAULT MISSION

		n_z Level										
Mission Segment	Flight Condition	0.4	0.5	0.6	0.7	0.8	1.2	1.3	1.4	1.5	1.6	1.7
Ascent	Steady State				0.0		0.0					
	Collective Pushover				0.0							
Level Flight	Steady State						0.0					
Descent	Collective Pull-Up						0.6					
	Unknown						1.5					
Full Power Climb	Steady State						1.8					
	Unknown							3.0				
Partial Power Descent	Steady State						0.0					
	Collective Pushover						0.0					
	Collective Pull-Up						0.0					
	Unknown							12.0	18.6			

TABLE 19. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR UH-1H ASSAULT MISSION

Gross Weight (lb)	Center of Gravity	Percent Time	n_z Level .5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7	1.8
6,000	141	1.618			1	3						
7,000	132	.007										
	133	.095										
	134	.899										
	135	4.69				1						
	136	13.63					1					
	137	22.15										
	138	19.29										
	139	9.38			2	5	4	1				
	140	2.54				2						
	141	.365										
	142	.029										
8,000	133	.068										
	134	.691										
	135	3.32										
	136	7.59										
	137	8.23										
	138	4.24				1						
	139	1.05										
	140	.121										
	141	.008										

TABLE 20. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR UH-1H ASSAULT MISSION

a) Hover

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less												
6000												
7000	6	7	1		1							15
8000		2										2
9000												
TOTAL	6	9	1		1							17

b) Descent

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less												
6000				1								1
7000	1											1
8000												
9000												
TOTAL	1			1								2

TABLE 21. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES FOR UH-1H ASSAULT MISSION

WEIGHT RANGE	Δn_z -.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
Less																
6000										1						1
7000							5		4	2						11
8000							1									1
9000																
TOTAL							6		4	3						13

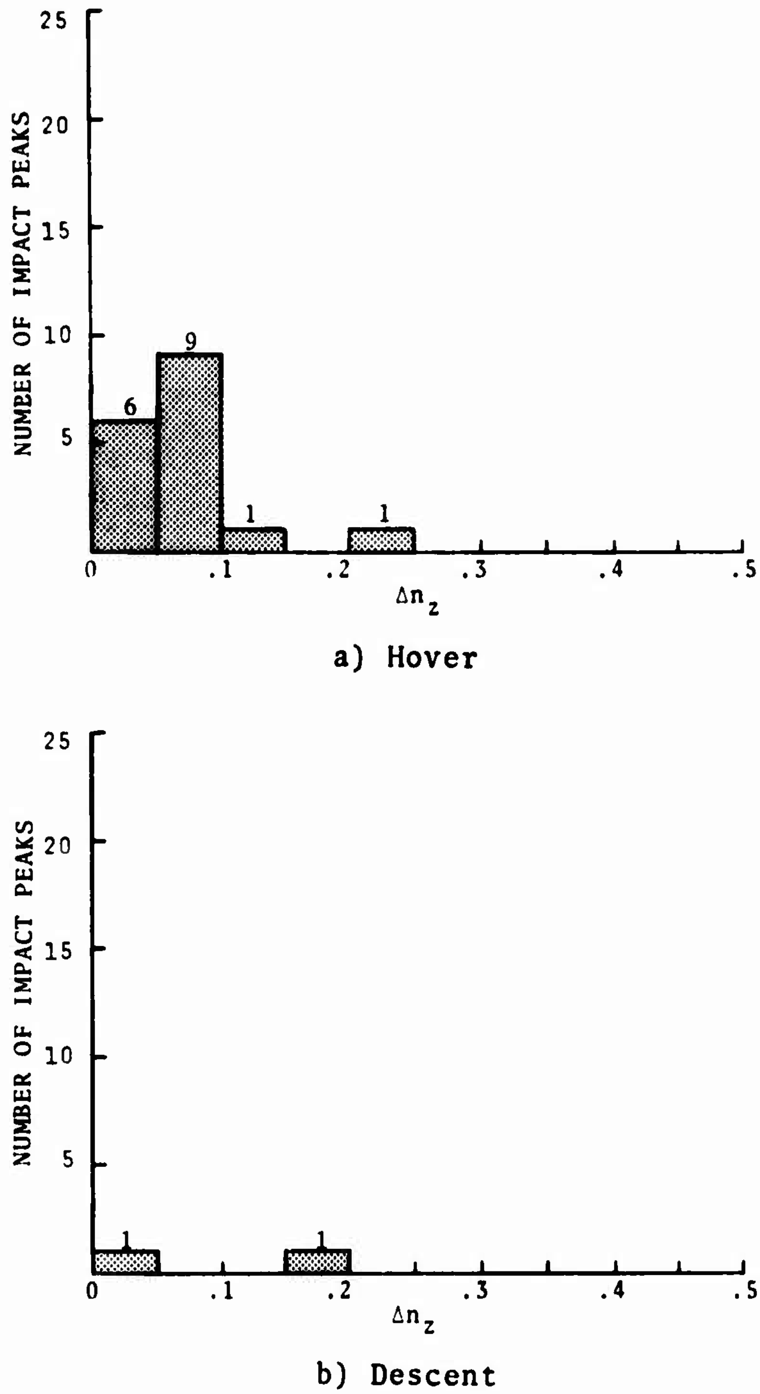

Figure 21. UH-1H Assault Landing Impact Peaks.

2.2.5 Transport - CH-47A Helicopter

The operational usage spectrum for the transport (CH-47A) helicopter is summarized in Table 22 which represents 22.9 hours of operational usage data. In this table, the largest percentages of time, namely, 40, 19, 18, and 17 percent, are in the ground operation, level, descent, and ascent mission segments, respectively. This distribution indicates that the aircraft flew from one area to another for loading and/or unloading cargo, most likely troops, while operating at ground idle on the landing site. In addition to the high percentage of operational time in ground operations, the frequencies of the flight conditions in this mission segment are greater than those in any other profile. There were 63 GAG cycles and 47 rotor start-stop cycles observed in the data sample. However, 13 of the rotor start-stop cycles occurred without a following takeoff. Thus, the operational spectrum substantiates the foregoing supposition of the aircraft performance and the high percentage of time in ground operations.

Only 4 percent of the flight time was spent in maneuvers. Table 23, which lists the maneuver n_z durations, indicates that the n_z's were generally mild and of short duration, with the pull-up and unknown flight conditions being the most severe maneuvers. Table 24 shows that as the gross weight increased, the frequency of maneuver n_z's generally decreased. This relationship indicates that the pilots flew more conservatively when the helicopters were carrying cargo.

As indicated in Table 25 and Figure 22, more landing impact Δn_z's occurred after landings from hover than after landings from descent. Still the greater number of n_z's from hover is not commensurate with the number of landings from hover which occurred almost twice as often as those from descent. Like Table 25, Table 26 distributes the frequency of taxi Δn_z's in Δn_z versus gross weight ranges. The large amount of time in ground operations and the CH-47A's capability of taxiing account for the large number of taxi n_z's, namely 875.

TABLE 22. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR CH-47A TRANSPORT MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				39.99
Rotor Start	205	-	-	
Steady State, Minimum	239	69	1.03	
Steady State, Average	239	373	5.59	
Steady State, Maximum	239	1787	26.80	
Transient	826	397	5.95	
Rotor Stop	205	-	-	
Ground Taxi	262	42	.62	
Hover:				5.91
Steady State, Minimum	156	27	.40	
Steady State, Average	156	69	1.03	
Steady State, Maximum	156	215	3.22	
Takeoff	201	38	.57	
Collective Pushover	22	1	.01	
Collective Pull-Up	48	8	.12	
Touchdown	223	-	-	
Cyclic Pushover	70	7	.10	
Cyclic Pull-Up	70	6	.10	
Longitudinal Reversal	57	5	.07	
Initiation of Ascent	66	12	.18	
Cargo Pickup	17	5	.07	
Cargo Drop	13	3	.04	
Ascent:				17.34
Steady State, Minimum	214	69	1.03	
Steady State, Average	214	323	4.85	
Steady State, Maximum	214	662	9.93	
Takeoff	153	20	.30	
Collective Pushover	188	23	.34	
Collective Pull-Up	87	8	.12	
Cyclic Pushover	66	7	.10	
Cyclic Pull-Up	96	15	.23	
Longitudinal Reversal	31	1	.01	
Initiation of Ascent	188	28	.42	
Mission Segment Change Without Maneuver	284	-	-	
Unknown Condition	17	1	.01	
Level Flight:				18.50
Steady State, Minimum	111	45	.67	
Steady State, Average	111	320	4.81	
Steady State, Maximum	111	852	12.79	
Collective Pushover	52	12	.18	
Collective Pull-Up	13	2	.03	
Cyclic Pushover	9	1	.01	
Cyclic Pull-Up	4	0	.00	
Mission Segment Change Without Maneuver	240	-	-	
Unknown Condition	13	1	.01	

TABLE 22. (Concluded)

Mission Segment Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Descent:				2.50
Steady State, Minimum	61	10	.15	
Steady State, Average	61	20	.31	
Steady State, Maximum	61	71	1.07	
Collective Pushover	44	6	.10	
Collective Pull-Up	61	10	.15	
Flare	70	39	.59	
Touchdown	39	-	-	
Cyclic Pushover	4	1	.01	
Cyclic Pull-Up	31	7	.11	
Mission Segment Change Without Maneuver	52	-	-	
Unknown Condition	4	1	.01	
Autorotation:				.07
Steady State	9	2	.03	
Power to Autorotation	9	2	.03	
Autorotation to Power	9	1	.01	
Partial Power Descent:				15.69
Steady State, Minimum	232	46	.69	
Steady State, Average	232	153	2.31	
Steady State, Maximum	232	656	9.85	
Collective Pushover	280	48	.72	
Collective Pull-Up	236	35	.53	
Flare	170	89	1.34	
Touchdown	83	-	-	
Cyclic Pushover	57	10	.15	
Cyclic Pull-Up	57	6	.10	
Longitudinal Reversal	4	0	.00	
Mission Segment Change Without Maneuver	87	-	-	
Cargo Drop	4	0	.00	
Unknown Condition	17	2	.03	

TABLE 23. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR CH-47A TRANSPORT MISSION

Mission Segment	Flight Condition	n_z Level .04	.05	.06	0.7	.08	1.2	1.3	1.4	1.5	1.6	1.7	1.8
Ascent	Steady State			.83	.29		.49						
	Collective Pushover			.53	.88		1.06	2.64					
	Collective Pull-Up						.95						
	Cyclic Pull-Up						.47						
	Longitudinal Reversal			.57			.36						
	Unknown Condition						.44						
Level Flight	Unknown Condition			.44	.29					.79			
Descent	Collective Pushover				.63								
	Collective Pull-Up						.22	1.03		4.24			
	Cyclic Pull-Up							4.17					
	Unknown Condition							2.86	3.14				
Autorotation	Steady State						.36						
	Power to Autorotation				1.43								
	Autorotation to Power							9.51					
Partial Power Descent	Steady State			.88	.79		.65						
	Collective Pushover				.47				1.76				
	Flare							.37					
	Cyclic Pull-Up							1.06	.73	1.17			
	Cargo Drop						.15						
	Unknown Condition						.43	1.03		2.11			

TABLE 24. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR CH-47A TRANSPORT MISSION

Gross Weight (lb)	Center of Gravity	Percent Time	n_z Level .5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7	1.8
<20,000	340	.003					3					
20,000	335	.070			2	1						
	336	1.74										
	337	9.45			2							
	338	10.92			4	3						
	339	2.79			1	1						
	340	.151			4							
	341	.003										
22,000	331	.021										
	332	.126										
	333	.604		3	7	9	3	1				
	334	2.00										
	335	8.05										
	336	9.89										
	337	8.34		1	14	23	8	3	2			
	338	5.09										
	339	2.22										
	340	.69										
	341	.15										
	342	.029										
24,000	328	.008										
	329	.049										
	330	.216										
	331	1.74										
	332	3.01		1	7	2	1					
	333	3.68			1	2	1					
	334	3.38		1	6	7						
	335	2.20										
	336	1.03										
	337	.35										
	338	.086										
	339	.016										
26,000	329	.013										
	330	1.45										
	331	5.99										
	332	1.37				3						
	333	.012										
28,000	327	.011										
	328	.041										
	329	.139										
	330	.365			2							
	331	.744										
	332	1.18										
	333	1.45										
	334	1.38										
	335	1.01					3					
	336	.58					1					
	337	.257						1				
	338	.089										
	339	.024										
	340	.005										

TABLE 25. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR CH-47A TRANSPORT MISSION

a) HOVER

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less												
20000		1	2	2	2	2	2	1	1			13
22000	1	1	4	10	5	2						23
24000			3	2	1	1	1					8
26000			2		1							3
28000						1	1					2
30000												
TOTAL	1	2	11	14	9	6	4	1	1			49

b) DESCENT

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less							1					1
20000			1	5	2	2	1	1				12
22000			3	3	4	1	2					13
24000			1	3	1		1	1				7
26000				1	1	1						3
28000								1				1
30000												
≥32000												
TOTAL			5	12	8	4	5	3				37

TABLE 26. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES FOR CH-47A TRANSPORT MISSION

WEIGHT RANGE	Δn_z -.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
Less				1		1	2		1		2					7
20000		2		1	7	25	93		99	27	12	2	2	1		271
22000				2	12	35	111		102	44	11	4				321
24000			1		4	23	69		65	21	10	5				198
26000					1	3	20		13	8	1					46
28000			1		1	2	14		11	1		1	1			32
30000																
≥32000																
TOTAL		2	2	4	25	89	309		291	101	36	12	3	1		875

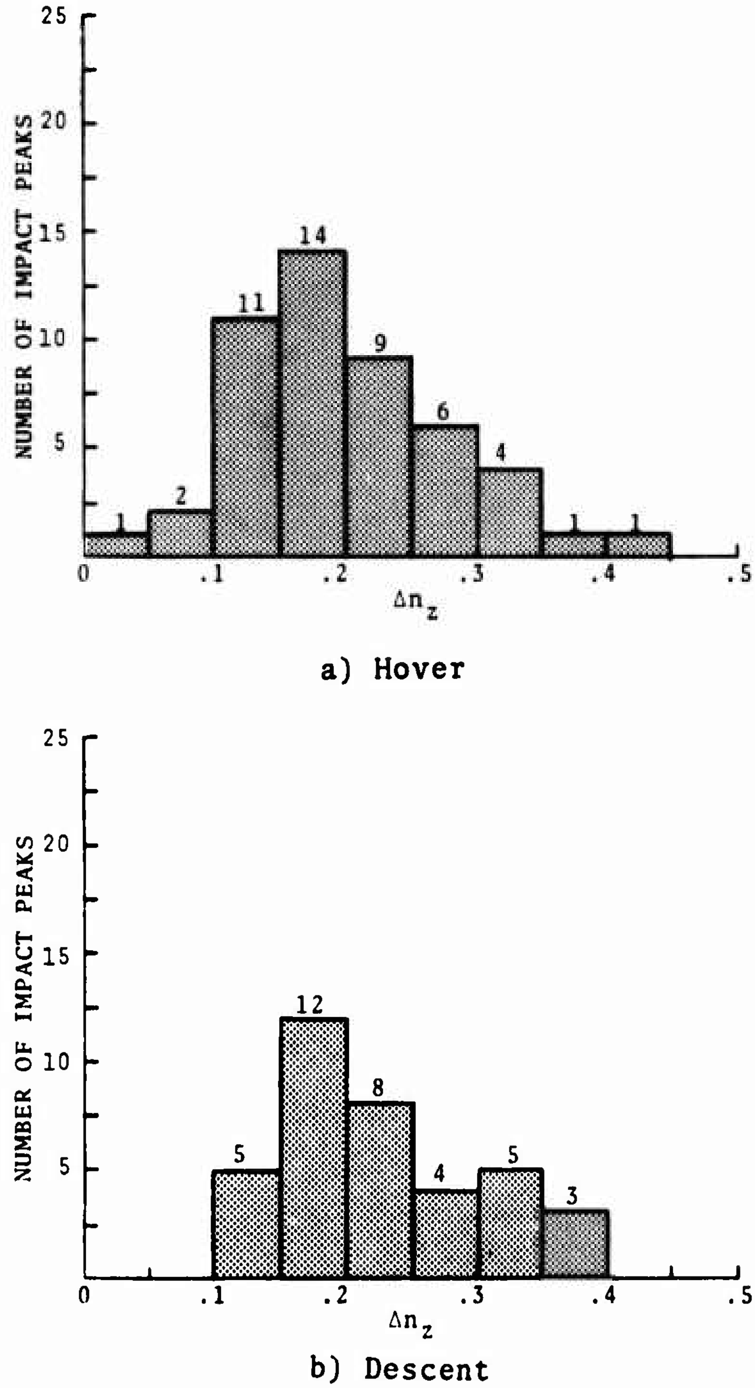

Figure 22. CH-47A Transport Landing Impact Peaks.

2.2.6 Utility - UH-1H Helicopter

The operational usage spectrum for the utility (UH-1H) helicopter is summarized in Table 27 which represents 15.3 of the 22.1 hours in the data sample. The 15.3 hours were selected since they were recorded in direct combat support, special, and streamliner types of missions which are generally representative of a utility helicopter. In this table, the highest percentages of flight time (26.19, 23.55, and 21.62), are in the level flight, ground operation, and ascent mission segments, respectively. This almost equal distribution among the three mission segments indicates that the aircraft flew from one area to another without appreciable deviation from its intended flight path. As further substantiation of this supposition, the helicopter was in the steady-state flight condition approximately 84 percent of the time.

There were 42 GAG cycles but only 8 rotor start-stop cycles observed in the data sample. The relatively low number of the rotor start-stop cycles was expected because of the aircraft's lack of an APU.

Although only 7 percent of the flight time was spent in maneuvers, Tables 28 and 29 indicate relatively numerous maneuver n_z's with long durations and high magnitudes in the collective pull-up and unknown flight conditions of the descent mission segment.

As for most of the other helicopters, most of the landings were from a hover. Table 30 and Figure 23 indicate that the landing impact Δn_z's from hover were 4 times as numerous as those from descent and that they occurred in medium weight ranges.

Like Table 30, Table 31 shows numerous taxi Δn_z's in the medium weight ranges. Again since the UH-1H is not equipped to taxi long, these n_z's were likely related to the landing impact Δn_z's, especially since most of the landings were from a hover.

TABLE 27. OPERATIONAL FLIGHT CONDITION FREQUENCY SPECTRUM FOR UH-1H UTILITY MISSION

Mission Segment / Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Ground Operations:				23.55
Rotor Start	52	-	-	
Steady State, Minimum	228	66	1.28	
Steady State, Average	228	228	4.42	
Steady State, Maximum	228	690	13.37	
Transient	685	226	4.38	
Rotor Stop	52	-	-	
Ground Taxi	13	5	.10	
Hover:				8.53
Steady State, Minimum	159	37	.72	
Steady State, Average	159	78	1.51	
Steady State, Maximum	159	241	4.67	
Takeoff	222	53	1.03	
Collective Pushover	65	7	.13	
Collective Pull-Up	52	6	.12	
Touchdown	280	-	-	
Initiation of Ascent	117	18	.35	
Mission Segment Change Without Maneuver	26	-	-	
Ascent:				21.62
Steady State, Minimum	176	67	1.30	
Steady State, Average	176	227	4.40	
Steady State, Maximum	176	736	14.27	
Takeoff	72	19	.37	
Collective Pushover	274	33	.64	
Collective Pull-Up	13	-	-	
Initiation of Ascent	46	5	.10	
Mission Segment Change Without Maneuver	144	-	-	
Unknown Condition Minimum	33	5	.10	
Unknown Condition Average	33	10	.19	
Unknown Condition Maximum	33	13	.25	
Level Flight:				26.19
Steady State, Minimum	209	88	1.71	
Steady State, Average	209	271	5.25	
Steady State, Maximum	209	879	17.04	
Collective Pushover	326	52	1.01	
Collective Pull-Up	157	22	.43	
Mission Segment Change Without Maneuver	65	-	-	
Unknown Condition, Minimum	35	9	.17	
Unknown Condition, Average	35	12	.23	
Unknown Condition, Maximum	35	18	.35	

TABLE 27. (Concluded)

Mission Segment Flight Condition	Occurrences Per 100 Hours	Time Per 100 Hours (Min)	Percentage of Flight Time	
Descent:				11.19
Steady State, Minimum	124	43	.83	
Steady State, Average	124	90	1.74	
Steady State, Maximum	124	352	6.82	
Collective Pushover	85	13	.25	
Collective Pull-Up	170	34	.66	
Flare	85	36	.70	
Touchdown	13	-	-	
Mission Segment Change Without Maneuver	20	-	-	
Unknown Condition	20	8	.15	
Full Power Climb:				.39
Steady State	26	20	.39	
Partial Power Descent:				8.57
Steady State, Minimum	196	25	.48	
Steady State, Average	196	57	1.10	
Steady State, Maximum	196	184	3.57	
Collective Pushover	352	49	.95	
Collective Pull-Up	202	40	.78	
Flare	130	80	1.55	
Unknown Condition, Minimum	16	2	.04	
Unknown Condition, Maximum	16	5	.10	

TABLE 28. AVERAGE TIME OUTSIDE n_z THRESHOLD IN SECONDS FOR UH-1H UTILITY MISSION

Mission Segment	Flight Condition	n_z Level 0.4	0.5	0.6	0.7	0.8	1.2	1.3	1.4	1.5	1.6	1.7
Ascent	Steady State				0.0		0.0					
	Collective Pushover				.08		0.0	1.2				
	Unknown			0.6	.52		2.1	2.5				
Level Flight	Steady State				0.0		0.0					
	Collective Pushover			3.0	.45							
	Collective Pull-Up						1.2					
	Unknown		1.2	1.2			3.14	3.60				
Descent	Steady State				0.0							
	Collective Pushover				.43		0.0					
	Collective Pull-Up				3.0		1.5	5.0	3.6			
	Unknown						1.2	6.0				
Partial Power Descent	Steady State				0.0		0.0					
	Collective Pushover				0.6							
	Collective Pull Up						1.5	4.56	20.4			
	Flare						3.9					
	Unknown						0.6	5.40	23.4			

TABLE 29. MANEUVER n_z PEAKS IN n_z RANGES VS GROSS WEIGHT AND CENTER-OF-GRAVITY RANGES FOR UH-1H UTILITY MISSION

Gross Weight(lb)	Center of Gravity	Percent Time	n_z Level .5	.6	.7	1.2	1.3	1.4	1.5	1.6	1.7	1.8
6,000	138	.001										
	139	.163			2	5	1	1				
	140	3.00		1								
	141	6.63										
	142	1.79										
	143	.055										
	144	.00										
7,000	132	.237										
	133	.668										
	134	1.55										
	135	2.20										
	136	5.35			9	10	6	2				
	137	6.13			4	1	1					
	138	6.50			3	2						
	139	5.99			1	1	1					
	140	4.49										
	141	2.70										
	142	1.42										
	143	.795			1							
	144	.206										
	145	.08										
8,000	131	.243										
	132	.799										
	133	2.41		1	8	6	4					
	134	5.11			2							
	135	8.08	1		8		2					
	136	9.42		1	1	2						
	137	8.08		1	4	11	3					
	138	5.11			7	16	3					
	139	2.41			3	4	4	2				
	140	.799										
	141	.243										
9,000	134	.035										
	135	.535										
	136	2.42										
	137	3.15										
	138	1.12										
	139	.13										

TABLE 30. LANDING IMPACT Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES BY HOVER AND DESCENT FOR UH-1H UTILITY MISSION

a) HOVER

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less 6000		5										5
7000	1	8	2	1	2		1					15
8000	3	6	2	2								13
9000	1	2										3
TOTAL	5	21	4	3	2		1					36

b) DESCENT

WEIGHT RANGE	Δn_z .00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	TOTAL
Less 6000												
7000	1	1			1							3
8000	1	1	4									6
9000												
TOTAL	2	2	4		1							9

TABLE 31. TAXI Δn_z PEAKS IN Δn_z VS GROSS WEIGHT RANGES FOR UH-1H UTILITY MISSION

WEIGHT RANGE	Δn_z -.40	-.35	-.30	-.25	-.20	-.15	-.10	-.05	.05	.10	.15	.20	.25	.35	.40	TOTAL
Less 6000									6							6
7000					1	2	9		15		1					28
8000					1	3	7		12	2						25
9000							1		1							2
TOTAL					2	5	17		34	2	1					61

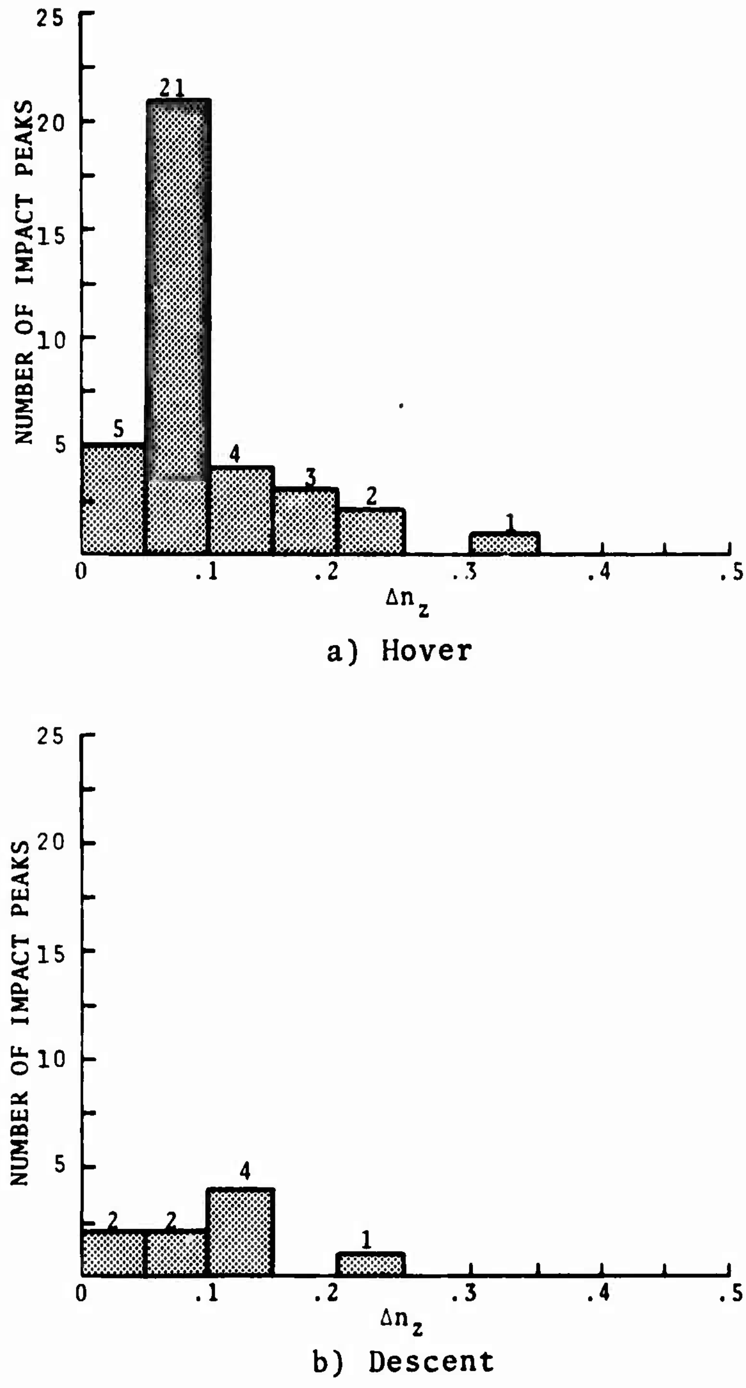

Figure 23. UH-1H Utility Landing Impact Peaks.

2.3 COMPARISON OF MANUFACTURER'S DESIGN AND NAVY AR-56 MISSION PROFILES WITH OPERATIONAL MISSION PROFILES INCLUDING GROUND TIME

2.3.1 General

In this section each of the six mission profiles developed from the SEA operational usage data is compared with the corresponding manufacturer's design and Navy AR-56 mission profile. For this comparison, the data in Tables 2, 7, 12, 17, 22, and 27, which present the operational spectrum of the flight condition frequency (generally in terms of the percentage of time spent in each flight condition with the ground time included) for each of the six helicopter class-model categories, were adjusted as necessary to the formats of the design spectra.

2.3.2 Attack - AH-1G Helicopter

To compare the mission profiles for the attack (AH-1G) helicopter, Table 32 lists the operational, design, and AR-56 spectra of the flight condition frequency. The design and AR-56 mission segment and flight condition data were taken from USAAMRDL Technical Report 73-41.[7] For the most part, the three spectra are in good agreement. The greatest differences are in ground conditions, level flight, gunnery maneuvers, and power-off flight. The large difference in the ground condition frequency is due solely to the fact that ground idle time was measured in the SEA data sample but not accounted for in the design or AR-56 spectra. Since the flight time includes the ground idle time, the accounting for the latter would prevent replacing components prematurely, i.e., before the actual flight time reached the component replacement time.

An oscillogram section recorded on the CH-47 (Figure 24) offers an example of ground operations, the associated flight conditions, and the corresponding ground time. However, ground operations did not always include a complete rotor start or stop, as shown in Figure 24, since the recording system could not function when its required power levels were not available; therefore, rotor starts and stops were processed as occurrences only; that is, their associated durations were not included in the processed data.

[7] Glass, Max E., Kidd, David L., and Norvell, John P., AH-1G DESIGN AND OPERATIONAL FLIGHT LOADS STUDY, Bell Helicopter Company; USAAMRDL Technical Report 73-41, U.S. Army Air Mobility R&D Laboratory, Fort Eustis, Virginia, January 1974, AD 775838.

TABLE 32. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR AH-1G ATTACK MISSION

DESIGN SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		1.00
a. Normal Start	0.50	
b. Shutdown W/coll	0.50	
c. -	-	
d. -	-	
e. -	-	
II. IGE Maneuvers		6.65
a. Takeoff		
1. Normal	0.90	
2. Jump	0.10	
b. Hovering		
1. Steady	2.17	
2. Right Turn	0.10	
3. Left Turn	0.10	
4. Control Reversal		
Longitudinal	0.01	
Lateral	0.01	
Rudder	0.01	
c. Sideward Flight		
1. To the Right	0.25	
2. To the Left	0.25	
d. Rearward Flight	0.25	
e. Acceleration		
1. Hover to climb A/S	0.50	
f. Deceleration		
1. Normal	0.70	
2. Quick Stop	0.30	
g. Approach and Landing	1.00	
h. -	-	
i. -	-	
j.		

OPERATIONAL SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		25.79
a. Rotor Start	(111)	
b. Rotor Stop	(111)	
c. Steady State	16.28	
d. Transient	9.51	
e. GAG	(186)	
II. IGE Maneuvers		8.55
a. Takeoff	.70	
1. -	-	
2. -	-	
b. Hovering		
1. Steady	6.10	
2. -	-	
3. -	-	
4. Control Reversal		
Longitudinal	.02	
-	-	
-	-	
c. -	-	
-	-	
-	-	
d. -	-	
e. -	-	
-	-	
f. -	-	
-	-	
-	-	
g. Flare	1.41	
h. Pull-Ups	.11	
i. Pushovers	.16	
j. Initiation of Ascent	.05	

AR-56 (ATTACK) SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		1.00
a. -		
b. -		
c. Steady	1.00	
d. GAG	(100)	
II. IGE Maneuvers		9.47
a. Takeoff		
1. Normal	.89	
2. -	-	
b. Hovering		
1. Steady	3.77	
2. Turns	.89	
3. -	-	
4. Control Reversal	.34	
-	-	
-	-	
-	-	
c. Sideward Flight	1.00	
1. -	-	
2. -	-	
d. Rearward Flight	.50	
e. -	-	
-	-	
f. -	-	
-	-	
-	-	
g. Approach	2.08	
h. -	-	
i. -	-	
j. -	-	

TABLE 32. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition		Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (ATTACK) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
III. Forward Level Flight			60.00	III. Forward Level Flight		33.71	III. Forward Level Flight		63.81
Airspeed	RPM								
a. 0.50 VH	314	0.50		a. All Airspeeds	33.71		a. .2-.5VH	5.45	
	324	4.50							
b. 0.60 VH	314	0.20		b. -	-		b. .6 VH	8.00	
	324	1.80							
c. 0.70 VH	314	0.30		c. -	-		c. .7 VH	8.00	
	324	2.70							
d. 0.80 VH	314	1.50		d. -	-		d. .8 VH	12.36	
	324	13.50							
e. 0.90 VH	314	2.50		e. -	-		e. .9 VH	15.00	
	324	22.50							
f. VH	314	1.00		f. -	-		f. VH	15.00	
	324	9.00							
IV. Nonfiring Maneuvers			19.55	IV. Nonfiring Maneuvers		30.44	IV. Nonfiring Maneuvers		16.72
a. Full Power Climb				a. Full Power Climb	.30		a. Full Power Climb		
1. Normal		4.00		1. -	-		1. Normal	3.00	
2. High-speed		1.00		2. -	-		2. High-Speed	1.00	
b. Maximum Rate Accel				b. Maximum Rate Accel	-		b. -	-	
c. Climb-Cruise A/S		2.80		c. Climb	11.87		c. -	-	
d. Normal Turns				d. Unknown Condition	4.63		d. Normal Turns		
1. To the Right				1. -	-		1. Right	3.50	
0.5 VH		1.10		-	-		-	-	
0.7 VH		1.00		-	-		-	-	
0.9 VH		2.00		-	-		-	-	
2. To the Left				2. -	-		2. Left	3.50	
0.5 VH		1.00		-	-		-	-	
0.7 VH		1.00		-	-		-	-	
0.9 VH		2.00		-	-		-	-	
3. 0.9 VH Control Reversal				3. Control Reversal			3. Control Reversal	1.67	
Longitudinal		0.50		Longitudinal	-		-	-	
Lateral		0.05		-	-		-	-	
Rudder		0.05		-	-		-	-	

TABLE 32. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (ATTACK) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
e. Sideslip	0.50		e. -	-		e. -	-	
f. Part Power Descent	2.55		f. Partial Power Descent	3.91		f. Partial Power Descent	2.08	
g. -	-		g. Pull-Ups	1.22		g. Pull-Ups	.97	
h. -	-		h. Pushovers	1.82		h. -	-	
i. -	-		i. Initiation of Ascent	.29		i. -	-	
			j. Other Descents	6.40		j. Power Dives	1.00	
V. Gunnery Maneuvers		9.4	V. Gunnery Maneuvers		1.50	V. Gunnery Maneuvers		5.40
a. Firing in a Hover	0.075		a. -	-		a. -	.10	
b. Strafing in Accel. from a Hover	0.05		b. -	-		b. -	-	
c. Gunnery Runs			c. Dives	.54		c. Dives	2.50	
1. PT. Target Dives			1. -	-		1. -	-	
To 0.6 VL	0.28		-	-		-	-	
To 0.8 VL	0.84		-	-		-	-	
To 0.9 VL	1.40		-	-		-	-	
To VL	0.28		-	-		-	-	
2. Spray Fire Dives			2. -	-		2. -	-	
To 0.6 VL	0.12		-	-		-	-	
To 0.8 VL	0.36		-	-		-	-	
To 0.9 VL	0.60		-	-		-	-	
To VL	0.12		-	-		-	-	
d. Gunnery Run Pull-Up			d. Dive Pull-Out	.92		d. Dive Pull-Out	.65	
1. To the Right			1. -	-		1. -	-	
0.6 VL	0.10		-	-		-	-	
0.8 VL	0.30		-	-		-	-	
0.9 VL	0.50		-	-		-	-	
2. To the Left			2. -	-		2. -	-	
0.6 VL	0.10							
0.8 VL	0.30							
0.9 VL	0.50							
VL	0.10							
3. Symmetrical			3. -	-		3. -	-	
0.6 VL	0.01							
0.8 VL	0.03							
0.9 VL	0.05							
VL	0.01							

TABLE 32. (Concluded)

DESIGN SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
e. Gunnery Turns		
1. To the Right		
0.5 VH	0.375	
0.7 VH	0.375	
0.9 VH	0.75	
2. To the Left		
0.5 VH	0.375	
0.7 VH	0.375	
0.9 VH	0.75	
3. S-Turns		
At 0.8 VH	0.20	
At VH	0.075	
VI. Power Transitions		.700
a. Power to Auto		
1. 0.5 VH	0.05	
2. 0.7 VH	0.125	
3. 0.9 VH	0.175	
b. Auto to Power		
1. In Ground Effect	0.15	
2. 0.4 VH	0.10	
3. 0.6 VH	0.075	
4. Max Auto A/S	0.025	
VII. Autorotation		3.15
a. Stabilized Flight		
1. 0.4 VH	0.20	
2. 0.6 VH	1.40	
3. Max Auto A/S	0.30	
b. Auto Turns		
1. To the Right		
0.4 VH	0.05	
0.6 VH	0.40	
Max Auto A/S	0.05	
2. To the Left		
0.4 VH	0.05	
0.6 VH	0.40	
Max Auto A/S	0.05	
c. Auto Landing	0.25	
d. -	-	
e. -		
f. -	-	

OPERATIONAL SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
e. -		
1. -	-	
2. -	-	
3. -	-	
VI. Power Transitions		.035
a. Power to Auto	.02	
1. -	-	
2. -	-	
3. -	-	
b. Auto to Power	.02	
1. -	-	
2. -	-	
3. -	-	
VII. Autorotation		.02
a. Steady	.02	
1. -	-	
2. -	-	
3. -	-	
b. -	-	
1. -	-	
2. -	-	
c. -	-	
d. Pull-Ups	0	
e. Pushovers	0	
f. -	-	

AR-56 (ATTACK) SPECTRUM

Mission Segment Basic Condition	Percentage of Flight Time	
e. Gunnery Turns		
1. Right	1.00	
2. Left	1.00	
3. S-Turns	.15	
VI. Power Transitions		.20
a. Power to Auto	.06	
1. -	-	
2. -	-	
3. -	-	
b. Auto to Power	.14	
1. -	-	
2. -	-	
3. -	-	
4. -	-	
VII. Autorotation		3.4
a. Steady	1.66	
1. -	-	
2. -	-	
3. -	-	
b. Auto Turns		
1. Right	.50	
2. Left	.50	
c. Auto Landing	.30	
d. Pull-Ups	.14	
e. -	-	
f. Control Reversals	.30	

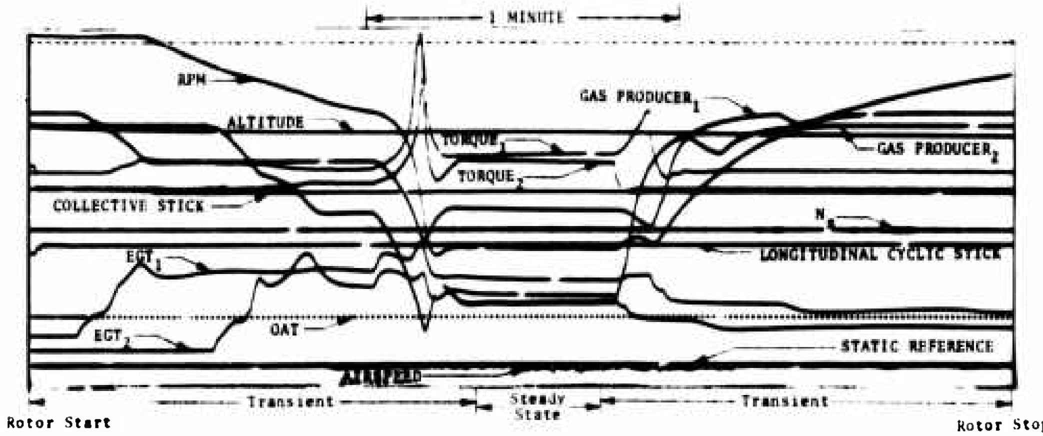

Figure 24. Oscillogram Showing Ground Operations.

Except for the absence of such flight conditions as sideward and rearward flight and hovering turns that depend on rudder and stick position data, not recorded on the oscillograms, the frequencies for the IGE maneuver mission segments compare well.

In the design and AR-56 spectra, the frequency for forward level flight seems much too high, even though airspeeds below 0.5 V_n were not considered in the design spectrum. As stated in Reference 6, "... it was anticipated that the ship would take off, cruise to the target area, accomplish the mission task, and cruise back to its base." Although this is likely true in conventional warfare, it was not true in the Vietnam theater where the helicopters generally responded to random-area needs and did not follow a regimented flight path. Such flying is indicative of NOE maneuvering employed during the SEA operations.

Although the total maneuver frequencies in the three spectra are almost equal, the nonfiring and gunnery maneuver frequencies in the design spectrum differ appreciably from those in the operational spectrum. Except for dives, gunnery maneuvers could not be easily distinguished on the oscillograms. Consequently, the firing runs noted on the supplemental data sheets had to be used as the primary means of distinguishing the maneuvers. But since there were frequently more dives recorded than reported, and vice versa, many of the nonfiring maneuvers in the SEA data sample could be gunnery maneuvers. In comparison with the operational spectrum, the short time in both the nonfiring and gunnery maneuvers in the AR-56 spectrum was due to the AH-1G flying NOE and frequently ascending and descending instead of flying a normal mission as anticipated.

The frequency of the turns in the design spectrum seems too high in comparison to the frequency of the unknown conditions in the operational spectrum which were likely turns. Since lateral cyclic stick and rudder pedal positions were not recorded, many low bank angle turns could not be identified; however, the most severe turns, i.e., unknowns, were identified.

The spectrum differences in the power-off flight are attributed to the fact that autorotations observed in the SEA data sample were of the training type since there was a power recovery for every autorotation and no autorotative landings. Consequently, the data sample was not sufficient to accurately define the power-off mission segment.

2.3.3 Crane - CH-54A Helicopter

To compare the mission profiles for the crane (CH-54A) helicopter, Tables 33 and 34 list the operational, design, and AR-56 spectra of the flight condition and mission segment frequencies. The design and AR-56 mission profile data were taken from USAAMRDL Technical Report 73-39.[8] Since the design and AR-56 spectra in Table 33 are gross breakdowns of the mission segments, they were expanded and refined in Table 34 according to the information given in a Sikorsky Aircraft document[9] and a U.S. Navy report,[10] respectively.

As evidenced by their frequency distributions, the design and AR-56 spectra were based on the assumptions that each CH-54A mission would consist of long periods of maneuverless level flight, cargo drops and pickups with large amounts of hover time, pilot training also with large amounts of hover time, and ascents and descents consistent with long flights. In contrast, the operational spectrum indicates that the missions were short flights with the consequent large amounts of time in ascent and descent. Since the hover time was short, the aircraft did not fly long in low-altitude maneuvering, obviously because of the hostile environment.

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[8] Mongillo, A.L., Jr., and Johnson, S.M., CH-54A DESIGN AND OPERATIONAL FLIGHT LOADS STUDY, Sikorsky Aircraft Division of United Aircraft; USAAMRDL Technical Report 73-39, U.S. Army Air Mobility R&D Laboratory, Fort Eustis, Virginia, November 1973, AD 773551.

[9] Franklin, C.E., CH-54A DESIGN FATIGUE SPECTRUM, Letter dated 20 October 1972, Sikorsky Aircraft, Stratford, Conn.

[10] STRUCTURAL DESIGN REQUIREMENTS (HELICOPTERS), NAVAL AIR SYSTEMS COMMAND, DEPARTMENT OF THE NAVY, Report AR-56, 17 February 1970.

TABLE 33. DESIGN, OPERATIONAL, AND AR-56 MISSION SEGMENT FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR CH-54A CRANE MISSION

DESIGN SPECTRUM			OPERATIONAL SPECTRUM			AR-56 (CRANE) SPECTRUM		
Mission Segment		Percent Time	Mission Segment		Percent Time	Mission Segment		Percent Time
I.	Ground	2.11	I.	Ground	9.38	I.	Ground	1.000
II.	Hover	21.385	II.	Hover, Steady	3.60	II.	Hover	16.000
III.	Sideward and Rearward Flight	2.175	III.	-	-	III.	Sideward and Rearward Flight	1.500
IV.	Ascent	8.422	IV.	Ascent, Steady	24.37	IV.	Ascent	5.670
V.	Descent	5.270	V.	Descent, Steady	21.97	V.	Descent	5.558
VI.	Cruise	53.240	VI.	Level Flight, Steady	28.25	VI.	Cruise	61.234
VII.	Takeoff Maneuvers	.02	VII.	Takeoffs	1.07	VII.	Takeoff Maneuvers	1.330
VIII.	Maneuvers	7.328	VIII.	Maneuvers	10.59	VIII.	Maneuvers	7.708
IX.	-		IX.	Cargo Pickup	.77	IX.	-	
X.	-		X.	Cargo Drop	.24	X.	-	

TABLE 34. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR CH-54A CRANE MISSION

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (CRANE) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground		0.00	I. Ground		11.81	I. Ground		1.00
a. Rapid Increase of RPM	(238)		a. Rotor Start/Stop	(27)		a. -	-	
b. Taxi Turns	(830)		b. Taxi	1.82		b. -	-	
c. Takeoff and Climb Out	(238)		c. Takeoff	2.43		c. Takeoff	(400)	
d. -	-		d. Steady	6.18		d. Steady	1.00	
e. -	-		e. Transient	1.38		e. -	-	
f. -	-		f. GAG	(126)		f. GAG	(100)	
II. Hovering		16.95	II. Hovering		3.62	II. Hovering		17.50
a. Steady	16.95		a. Steady	3.60		a. Steady	16.00	
b. Reversals			b. Reversals			b. Reversals	(1000)	
1. Lateral	(475)		1. -	-		1. -	-	
2. Longitudinal	(475)		2. Longitudinal	.02		2. -	-	
3. Rudder	(475)		3. -	-		3. -	-	
c. Left Sideward	(142)		c. -	-		c. Sideward	1.00	
d. Right Sideward	(142)		d. -	-		d. -	-	
e. Rearward	(142)		e. -	-		e. Rearward	.50	
f. Hovering Turns			f. -	-		f. Hovering Turns	(1000)	
1. Left	(120)					1. -	-	
2. Right	(120)					2. -	-	
III. Forward Flight		58.01	III. Forward Flight		84.57	III. Forward Flight		81.5
a. Climb	(238)		a. -			a. Takeoff Power Climb	3.00	
b. -	-		b. Full Power Climb	.18		b. Full Power Climb	4.00	
c. -	-		c. Other Ascents	24.19		c. -	-	
d. Level Flight	52.97		d. Level Flight	28.25		d. Level Flight	65.00	
e. Right Turns	2.40		e. Unknown	.02		e. Right Turn	2.50	
f. Left Turns	2.40		f. -	-		f. Left Turn	2.50	
g. Power to Auto	(20)		g. -	-		g. Power to Auto	(40)	
h. Steady Auto	.24		h. -	-		h. Steady Auto	2.0	
i. Auto to Power	(20)		i. -	-		i. Auto to Power	(40)	
j. Partial Power Descent	(75)		j. Partial Power Descent	8.38		j. Partial Power Descent	(500)	
k. -	-		k. Other Descents	13.59		k. Power Dives	2.50	

TABLE 34. (Concluded)

DESIGN SPECTRUM		OPERATIONAL SPECTRUM		AR-56 (CRANE) SPECTRUM	
Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time
l. Symmetrical Pull Outs	(475)	l. Pull-Ups	2.80	l. Pull-Ups	(290)
m. -	-	m. Pushovers	4.17	m. -	-
n. Control Reversals	(950)	n. -	-	n. Control Reversals	(800)
o. Landing Approach	(119)	o. Flare	1.98	o. Landing Approach	(500)
p. Hover Approach	(119)	p. -	-	p. -	-
q. -	-	q. Cargo Pickup	.77	q. -	-
r. -	-	r. Cargo Drop	.24	r. -	-

In the operational spectrum, the ground time includes the time for ground idle, ground taxi, and transient operation. Although the ground time does not include all the time for rotor start and stop since the recording system was operated at the pilot's discretion, the ground taxi and ground idle apparently lasted longer than anticipated in the design and AR-56 spectra.

Since the design and AR-56 spectra shown in Table 33 are quite similar, they were likely based on the CH-54A design profile. Therefore, before future crane helicopters become operational, the AR-56 profile should be modified to be representative of all crane aircraft.

If the design spectrum of Table 34 is compared with the operational spectrum of Table 7 on the basis of occurrences only, all operational flight conditions, except taxis, takeoffs, and reversals, occurred more frequently than anticipated by the design spectrum. In Table 34, most of the flight conditions in the design spectrum are represented as occurrences rather than percentages of flight time. Since the remaining flight conditions are represented as percentages of time which do not total to 100 percent, the listed occurrences are part of the total flight time. Therefore, these occurrences should be converted to percentages to permit meaningful comparisons.

2.3.4 Observation - OH-6A Helicopter

To compare the mission profiles for the observation (OH-6A) helicopter, Table 35 lists the operational, design, and AR-56 spectra of the flight condition frequency. The design mission segment and flight condition data were taken from USAAMRDL Technical Report 73-21.[11] The major differences between the operational, design, and AR-56 spectra are in the frequencies for maneuver, ground operation, hover, level flight, and autorotation.

The greater frequency for maneuvers in the operational spectrum is attributed to the combat zone environment where the helicopter generally flew NOE to detect enemy positions and upon receiving enemy fire took evasive action with its high maneuverability.

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[11] OH-6A DESIGN AND OPERATIONAL FLIGHT LOADS STUDY, Hughes Helicopters; USAAMRDL Technical Report 73-21, U.S. Army Air Mobility R&D Laboratory, Fort Eustis, Virginia, January 1974, AD 775832.

TABLE 35. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR OH-6A OBSERVATION MISSION

DESIGN SPECTRUM		OPERATIONAL SPECTRUM		AR-56 (UTILITY) SPECTRUM	
Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time
I. Ascent	6.5	I. Ascent	8.74	I. Ascent	4.5
a. Maximum performance takeoff	0.50	a. Takeoff	.51	a. Takeoff	0.98
b. Climb (takeoff power)	2.00	b. Climb (takeoff power)	-	b. Climb (takeoff power)	0.88
Climb (maximum continuous power)	4.0	Climb (full power)	1.74	Climb (full power)	2.64
		Climb (other)	6.49		
II. Maneuver	16.6	II. Maneuver	25.95	II. Maneuver	8.08
a. Longitudinal, Lateral and Pedal Reversal, Hover	1.50	a. Longitudinal Reversal Hover	.03	a. Control Reversal Hover	0.73
b. Turn, Hover	-	b. -	-	b. Turn, Hover	1.47
c. Right Turns, 30, 60, 90% V_{NE}	3.00	c. -	-	c. Right Turn	2.20
Left Turns, 30, 60, 90% V_{NE}	3.00		-	Left Turn	2.20
d. Autorotation Entry - 30, 60, 90% V_{NE}	1.50	d. -	-	d. Autorotation Entry	0.03
e. Pull-Up	1.00	e. Pull-Up		e. Pull-Up	0.18
		Collective	8.09		
		Cyclic	.11		
f. Longitudinal, Lateral and Pedal Reversal	1.50	f. Longitudinal Reversal	.24	f. Control Reversal	0.59
g. Simulated Power Failure	0.10	g. -	-	g. -	-
h. Pushover	-	h. Pushover		h. -	-
		Collective	6.77		
		Cyclic	.73		
i. Power Recovery from Autorotation	0.50	i. -	-	i. Power Recovery from Autorotation	0.03

TABLE 35. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
j. Right Turns at 30, 60, 90% V_{NE} Autorotation	1.00		j. -	-		j. Right Turn, Autorotation	0.18	
Left Turns at 30, 60, 90% V_{NE} Autorotation	1.00					Left Turn, Autorotation	0.18	
k. Longitudinal, Lateral and Pedal Reversal Autorotation	1.50		k. -	-		k. Control Reversal Autorotation	0.26	
l. Pull-Up, Autorotation	1.00		l. -	-		l. Pull-Up, Autorotation	0.03	
m. -	-		m. Initiation of Ascent	.50		m. -	-	
n. -	-		n. Unknown Condition	9.48		n. -	-	
III. Descent		7.00	III. Descent		7.02	III. Descent		8.21
a. Partial Power Descent	2.00		a. Partial Power Descent	.19		a. Partial Power Descent	4.89	
b. Rapid Transition and Flare	3.00		b. Flare	.64		b. Landing Approach	3.06	
Approach to Hover	-							
c. -	-		c. Other Descents	6.19		c. -	-	
d. Autorotation Landing, Including Approach and Flare	2.00		d. -	-		d. Autorotation Landing	0.26	
IV. Steady State		69.90	IV. Steady State		58.30	IV. Steady State		79.21
a. -	-		a. Ground Conditions	23.53		a. Ground Conditions	0.88	
b. Hover, in Ground Effect (IGE)	0.50		b. Hover (IGE)	2.86		b. Hover	8.80	
Hover, Out of Ground Effect (OGE)	-							

TABLE 35. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time
c. Level Flight at 20% V_{NE}	1.00	c. Level Flight	21.17	c. 20% V_H	4.40
Level Flight at 40% V_{NE}	3.00			40% V_H	4.40
Level Flight at 60% V_{NE}	18.00			50% V_H	1.76
Level Flight at 80% V_{NE}	25.30			60% V_H	7.04
V_H	15.00			70% V_H	8.80
V_{NE}	3.00			80% V_H	13.20
111% V_{NE}	0.60			90% V_H	15.85
				V_{NE}	8.80
				115% V_H	0.88
				Power Dives	2.20
d. Sideward Flight	0.50	d. -	-	d. Sideward Flight	0.88
Rearward Flight	0.50			Rearward Flight	0.44
e. Autorotation	2.00	e. -	-	e. Autorotation	0.88
f. -	-	f. IGE Maneuver	10.74	f. -	-
g. Rotor Start	.25	g. Rotor Start	(78)	g. -	-
h. Rotor Stop	.25	h. Rotor Stop	(78)	h. -	-
i. -	-	i. GAG	(228)	i. GAG	(100)

The poor correlation of the AR-56 spectrum with either of the other two spectra is due to its representing a utility, rather than an observation, helicopter. Whereas the observation helicopter flies NOE within or near enemy lines, the utility helicopter flies more conservatively, well within friendly territory.

In the operational spectrum, the ground operation consisted mainly of ground idle, and the hover frequency was low because of the combat environment. Whereas the hover frequency in the AR-56 spectrum is too high, the hover frequencies for the operational and design spectra would be in fairly close agreement if the sideward and rearward flight frequencies were added to the hover frequency in the design spectrum.

The lack of autorotations in the operational spectrum was due to the fact that the instrumented OH-6A helicopters did not experience any engine failures or practice autorotations.

2.3.5 Assault - UH-1H Helicopter

As previously stated, to prepare the mission profile for the UTTAS (UH-1H) helicopter, 6.8 of the 22.1 hours in the UH-1H data sample were selected since they were recorded in assault, command and control, and ELSA types of missions which are generally representative of the assault operation in a UTTAS helicopter mission profile. The operational mission profile data were taken from Reference 4. Since there is no mission segment-flight condition frequency spectrum for the UTTAS as an assault helicopter, the following data were used to compare the operational and design mission profiles for the UH-1H and the UTTAS operating as assault helicopters: n_z exceedance curves in Figure 25, an n_z versus airspeed envelope in Figure 26, and curves of the cumulative percentage of time in airspeed ranges in Figure 27. Tabular data for these figures are presented in Tables 36 and 37.

In Figure 25, the operational curves fall inside the design curves, as expected, since the UTTAS helicopter with its frequent NOE flights will likely have n_z's whose frequency and magnitude are normally greater than those of a helicopter flying only utility missions such as in SEA.

In Figure 26, the operational n_z versus airspeed frequencies are plotted on the design aerodynamic and structural envelope for the UTTAS helicopter. Obviously, the UH-1H operated as an assault helicopter would never exceed the limits of this envelope.

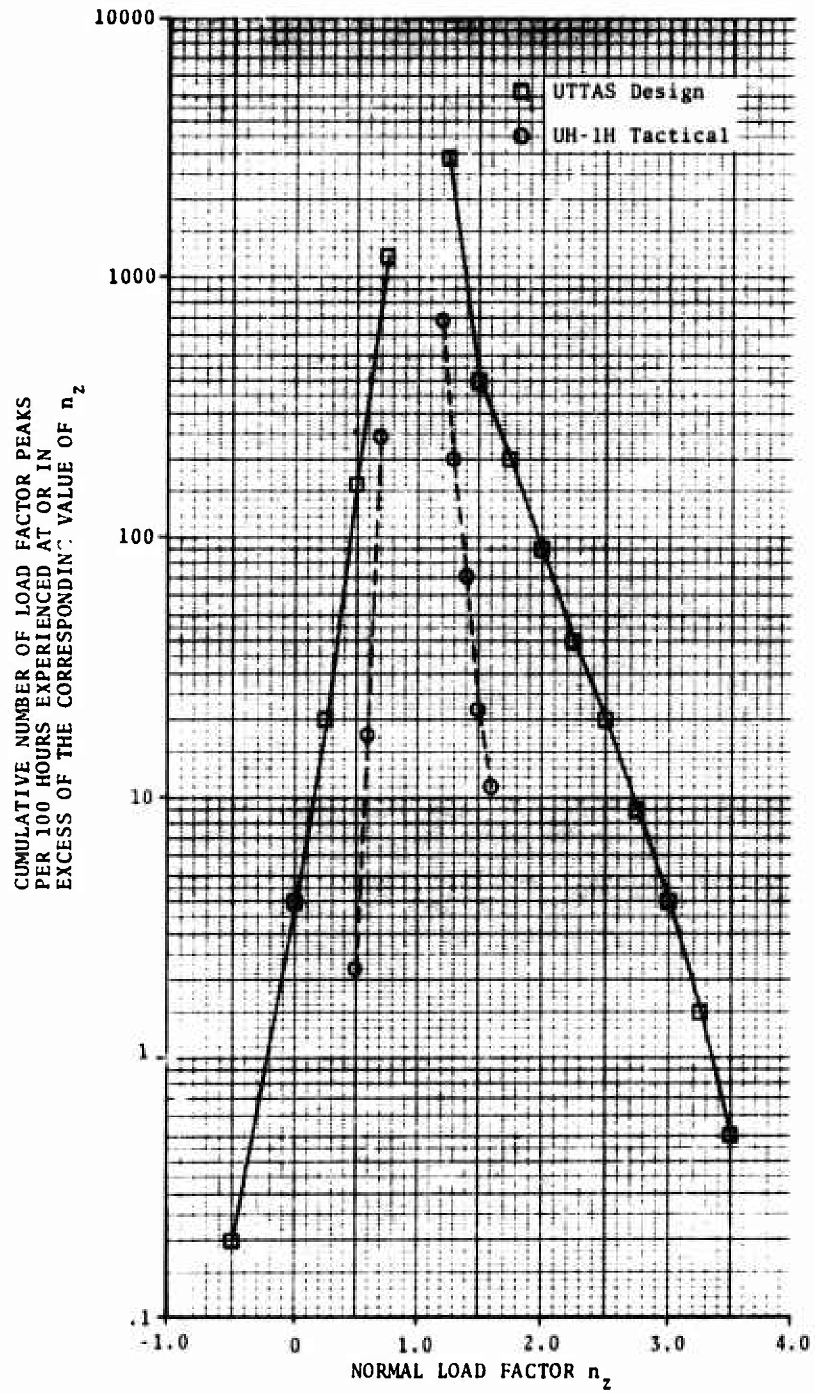

Figure 25. Cumulative Maneuver-Induced Normal Load Factor Distribution.

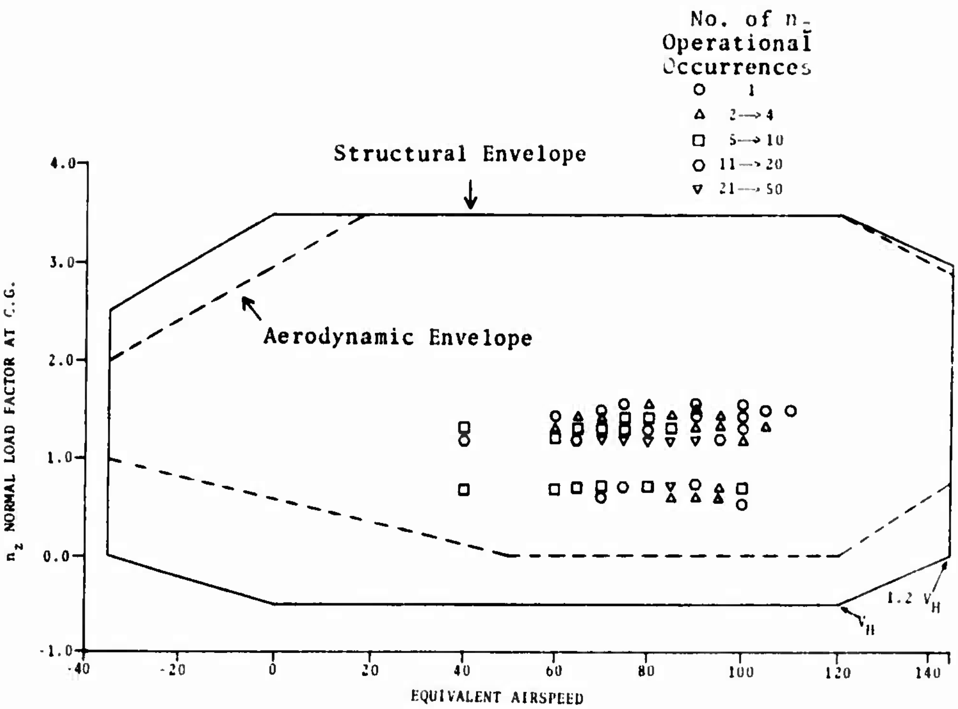

Figure 26. UTTAS n_z Design Envelopes with Operational n_z Occurrences.

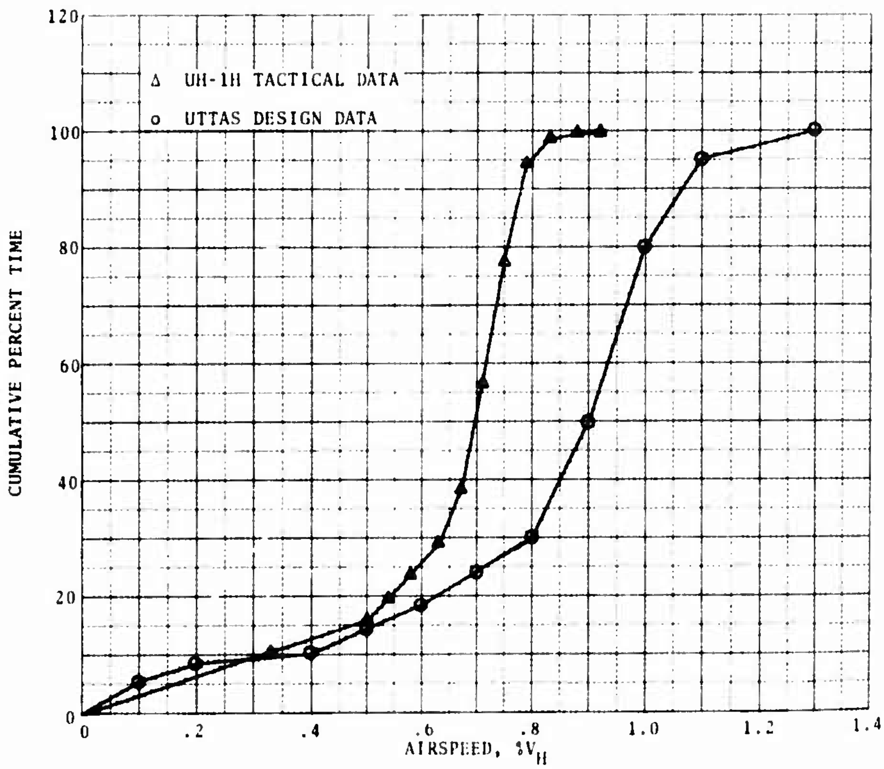

Figure 27. UTTAS and Assault - UH-1H Airspeed Frequency Distribution.

TABLE 36. OPERATIONAL ASSAULT - UH-1H AND UTTAS DESIGN n_z EXCEEDANCE SPECTRA

Peak Load Factor, n_z	Occurrence in n_z Level for the Operational Tactical (UH-1H)	Occurrence in n_z Level Per 100 Hours for the Operational Tactical (UH-1H)	Cumulative Exceedances Per 100 Hours for the Operational Tactical (UH-1H)	Cumulative Exceedances Per 100 Hours for the UTTAS
3.5				.5
3.25				1.5
3.00				4.0
2.75				9.0
2.50				20.0
2.25				40.0
2.00				90.0
1.75				200.0
1.6	5.0	11.0	11.0	
1.5	5.0	11.0	22.0	400.0
1.4	22.0	48.4	70.4	
1.3	59.0	129.8	200.2	
1.25				2900.0
1.2	218.0	479.6	679.8	
.75				1200.0
.7	103.0	226.6	244.2	
.6	7.0	15.4	17.6	
.5	1.0	2.2	2.2	160.0
.4				
.25				20.0
0				4.0
-.5				.2

TABLE 37. MANEUVER n_z PEAKS IN n_z VS AIRSPEED RANGES FOR ASSAULT - UH-1H MISSION

n_z	Airspeed														
	Less	40	60	65	70	75	80	85	90	95	100	105	110	115	Total
1.6						1	2		1		1				5
1.5					1				2			1	1		5
1.4			1	2	2	5	5	2	1	3	1				22
1.3	2	6	4	5	9	5	13	6	4	4	1	3			59
1.2	10	19	9	20	27	26	28	35	23	14	4				218
.7	6	8	8	8	9	15	9	21	12	2	5				103
.6					1			2	2	2					7
.5											1				1
Total	18	33	22	35	49	52	57	66	45	25	13	4	1	0	420

In Figure 27 for the cumulative percentage of time at or below a given airspeed, the curves indicate that the UH-1H had much slower airspeeds than those in the criteria for the UTTAS helicopter. As apparent, the UH-1H spent 70.9 percent of its time between 0.6 and 0.8 V_n while the UTTAS is designed to spend 70 percent of its time between 0.8 and 1.2 V_n. However, such differences would be expected since the UTTAS has more power available and the power of the UH-1H was limited because of the high density altitudes in the SEA operation. At the lower airspeeds, the UH-1H and UTTAS airspeed distributions are quite similar, as expected, since the two aircraft perform virtually the same operation at these airspeeds.

2.3.6 Transport - CH-47A Helicopter

To compare the mission profiles for the transport (CH-47A) helicopter, Table 38 lists the operational, design, and AR-56 spectra of the flight condition frequency. The design mission segment and flight condition data were taken from USAAMRDL Technical Report 73-40.[12] The considerable differences between the three spectra are due to the CH-47A flying relatively short flights which required more ascents and descents and minimal hovers in combat zones.

[12] Herskovitz, A., and Steinmann, H., CH-47A DESIGN AND OPERATIONAL FLIGHT LOADS STUDY, Boeing-Vertol Company; USAAMRDL Technical Report 73-40, U.S. Army Air Mobility R&D Laboratory, Fort Eustis, Virginia, November 1973, AD 772949.

TABLE 38. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR CH-47A TRANSPORT MISSION

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (CARGO) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
I. Steady Level Segment		80.0	I. Steady Level		22.9	I. Steady Level		73.90
a. Hover	10.0		a. Hover	4.65		a. Hover	10.50	
b. Transition	10.0		b. Transition	-		b. -	-	
c. .9 V_h	50.0		c. Level Flight	18.25		c. Level Flight	63.40	
d. 1.0 V_h	10.0		d. -	-		d. -	-	
II. Steady Ascent		6.0	II. Steady Ascent		15.80	II. Steady Ascent		3.60
a. Climb	-		a. Climb			a. Climb		
1. Full Power	6.0		1. Full Power	-		1. Full Power	2.70	
2. Takeoff Power	0.0		2. Takeoff Power	-		2. Takeoff Power	.90	
3. -	-		3. Other	15.80		3. -	-	
III. Steady Descent		4.0	III. Steady Descent		14.36	III. Steady Descent		6.40
a. Partial Power	-		a. Partial Power	12.82		a. Partial Power	3.30	
b. Autorotation	4.0		b. Autorotation	.03		b. Autorotation	.90	
c. Dive	-		c. -	-		c. Dive	2.20	
d. -	-		d. Other	1.51		d. -	-	
IV. Maneuver		10.0	IV. Maneuver		46.82	IV. Maneuver		16.10
a. Ground Condition			a. Ground Condition			a. Ground Condition		
1. Rotor Start	.5		1. Rotor Start/Stop		(410)	1. Rotor Start	.90	
2. Taxi	.5		2. Taxi	.63		2. -	-	
3. -	-		3. Steady	33.42		3. -	-	
4. -	-		4. Transient	5.95		4. -	-	
5. -	-		5. GAG		(275)	5. GAG	.50(100)	
b. Takeoff	.5		b. Takeoff	1.47		b. Takeoff	.50	
c. Sideward Flight	.5		c. -	-		c. Sideward Flight	.90	
d. Rearward Flight	.5		d. -	-		d. Rearward Flight	.40	
e. Symmetric Maneuvers			e. Symmetric Maneuvers			e. Symmetric Maneuvers		
1. Pull-Up 1.4 g	.5		1. Pull-Ups	1.44		1. Pull-Up 1.4g	.40	
2. Auto Pull-Up	.5		2. -			2. Auto Pull-Up	.20	
3. Change to PPD	.5		3. -			3. -	-	
4. -	-		4. Pushovers	1.71		4. -	-	
5. -	-		5. Power to Auto	.03		5. Power to Auto	.10	
6. -	-		6. Auto to Power	.01		6. -	-	

TABLE 38. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	AR-56 (CARGO) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time
f. Turns		f. Unknown	.06	f. Turns	
1. Hover	1.5			1. Hover	2.40
2. Left Level	1.5			2. Left Level	2.20
3. Right Level	1.5			3. Right Level	2.20
4. Left Descending	.5			4. Left Descending	.20
5. Right Descending	.5			5. Right Descending	.20
g. Control Reversals	-	g. Control Reversals		g. Control Reversals	
		1. Longitudinal	.08	1. Hovering and Flight	1.50
h. Yawing	.5	h. Yawing	-	h. -	-
i. Landing		i. Landing		i. Landing	
1. Flare	1.0	1. Flare	1.91	1. Approach	3.20
2. Autorotation to Ldg.	.5	2. -		2. Autorotation to Landing	.30
j. -	-	j. Cargo Pickup	.07	j. -	-
k. -	-	k. Cargo Drop	.04	k. -	-

Whereas the taxi frequencies are in good agreement, the total ground frequencies are much higher in the operational spectrum. As seen in Table 38, the operational steady-state ground time represents 33.4 percent of the total mission time. This large percentage was due mostly to the fact that after the helicopter landed to discharge passengers and cargo, its engines kept running in preparedness for immediate takeoff in the event of enemy attack. Since this ground time was likely included in the log books as flight time, as previously stated, components would have been replaced prematurely, i.e., before the required component replacement time. Consequently, the design and AR-56 mission profiles should be modified to represent the time in steady-state ground operations.

If the ground maneuver frequencies are ignored when comparing the spectra, the remaining total maneuver frequencies for the three spectra are in close agreement but vary considerably among the types of maneuvers. For example, the pull-up and pushover frequencies in the operational spectrum are much higher than those in the design and AR-56 spectra, and the turn frequencies in the design and AR-56 spectra are much higher than the unknown condition (most likely turns) frequency in the operational spectrum.

2.3.7 Utility - UH-1H Helicopter

To compare the mission profiles for the utility (UH-1H) helicopter, Table 39 lists the operational, design, and AR-56 spectra of the flight condition frequency. The design and AR-56 mission segment and flight condition data were taken from the report of Orr et al.[13] and Reference 10, respectively. However, since the original AR-56 utility mission spectrum, shown in Table 40, has several conditions expressed in terms of occurrences, the following adjustments were made before the data in this spectrum was adapted to the design spectrum format for presentation in Table 39. First, as shown in Table 41, these occurrences were converted to percentages of flight time by using assumed occurrence durations based on similar Bell data. Next, the resultant percentages of time in Table 41 were incorporated in the AR-56 utility mission spectrum by making corresponding reductions in the percentages of flight time for the applicable steady-state conditions in Table 40. Then the adjusted AR-56 utility mission spectrum, shown in Table 42, was adapted to the design spectrum format as shown in Table 39.

[13] Orr, P., McLeod, G., and Goodell, W., FATIGUE LIFE SUBSTANTIATION OF DYNAMIC COMPONENTS FOR THE UH-1D HELICOPTER EQUIPPED WITH THE 48-FOOT DIAMETER ROTOR, Report No. 205-099-135, Bell Helicopter Company, Fort Worth, Texas.

TABLE 39. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME INCLUDED FOR UH-1H UTILITY MISSION

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		1.00	I. Ground Conditions		23.55	I. Ground Conditions		1.00
a. Normal Rotor Start	0.50		a. Rotor Start	(52)		a. -	-	
b. Normal Shutdown	0.50		b. Rotor Stop	(52)		b. -	-	
c. -	-		c. Steady	19.07		c. Steady	1.00	
d. -	-		d. Transient	4.38		d. -	-	
e. -	-		e. Taxi	.10		e. -	-	
f. -	-		f. GAG	(548)		f. GAG	(100)	
II. Power-on Flight		94.82	II. Power-on Flight		76.45	II. Power-on Flight		97.00
a. Vertical Take-off	0.40		a. Takeoffs	1.40		a. Takeoff	.89	
b. Hovering IGE			b. IGE Hover			b. Hover		
1. Steady	3.29		1. Steady	6.90		1. Steady	6.95	
2. Right Turn	0.10					2. Turns	2.22	
3. Left Turn	0.10					3. -	-	
4. Control Reversal						4. Control Reversal	.83	
a. Longitudinal	0.01					-	-	
b. Lateral	0.01					-	-	
c. Rudder	0.01					-	-	
c. Normal Acceleration	1.00		c. -	-		c. -	-	
d. Normal Deceleration	1.00		d. -	-		d. -	-	
e. Max Rate Accel.	0.25		e. -	-		e. -	-	
f. Max Rate Decel.	0.25		f. -	-		f. -	-	
g. Sideward Flight			g.	-		g. Sideward Flight	1.00	
1. To the Right	0.25							
2. To the Left	0.25							
h. Rearward Flight	0.25		h. -	-		h. Rearward Flight	.50	
i. Full Power Climb	4.00		i. Full Power Climb	.39		i. Full Power Climb	3.00	
j. Forward Level Flight			j. Level Flight, Steady	24.00		j. Forward Level Flight		
1. 0.2 Vne	1.00					1. .2	3.03	
2. 0.3	1.00					2. -	-	
3. 0.4	2.00					3. .4	2.92	
4. 0.5	3.00					4. .5	1.00	
5. 0.6	7.00					5. .6	8.00	
6. 0.7	8.00					6. .7	10.00	
7. 0.8	15.00					7. .8	13.84	
8. 0.9 Vne	25.00					8. .9	18.00	
9. Vne	15.00					9. VH	10.00	

TABLE 39. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	DESIGN SPECTRUM Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	OPERATIONAL SPECTRUM Percentage of Flight Time	AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	AR-56 (UTILITY) SPECTRUM Percentage of Flight Time
k. Part-Power Descent	1.00	k. Partial Power Descent	5.15	k. Partial-Power Descent	2.03
l. Right Turns		l. Unknowns	1.58	l. Right Turns	2.5
1. 0.3 V_H	0.50			1. -	-
2. 0.6 V_H	1.00			2. -	-
3. 0.9 V_H	0.50			3. -	-
m. Left Turns		m. -	-	m. Left Turns	2.5
1. 0.3 V_H	0.50			1. -	-
2. 0.6 V_H	1.00			2. -	-
3. 0.9 V_H	0.50			3. -	-
n. Cyclic Pull-Ups		n. Cyclic Pull-Ups	-	n. Pull-Ups	.49
1. 0.6 V_H	0.20			1. -	-
2. 0.9 V_H	0.05			2. -	-
o. Collective Pull-Ups		o. Collective Pull-Ups	1.99	o. -	-
1. 0.6 V_H	0.20				
2. 0.9 V_H	0.05				
p. 0.9 V_H Control Reversal		p. Control Reversal	-	p. Control Reversals	.67
1. Longitudinal	0.05	1. Longitudinal	-	1. -	-
2. Lateral	0.05			2. -	-
3. Rudder	0.05			3. -	-
q. Normal Landing		q. -	-	q. -	-
1. 6500 lb Gross Weight	0.10				
2. 7500 lb Gross Weight	0.30				
3. 8500 lb Gross Weight	0.45				
4. 9500 lb Gross Weight	0.15				
r. -	-	r. Collective Push-overs	2.98	r. -	-
s. -	-	s. Descent	9.39	s. -	-
t. -	-	t. Ascent	19.97	t. Takeoff Power Climb	1.0
u. -	-	u. Initiation of Ascent	.458	u. -	-
v. -	-	v. Flare	2.25	v. Landing Approach	2.08
w. -	-	w. -	-	w. Power Dives	3.5

TABLE 39. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	DESIGN SPECTRUM Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	OPERATIONAL SPECTRUM Percentage of Flight Time	AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	AR-56 (UTILITY) SPECTRUM Percentage of Flight Time
III. Transitions	.700	III. Transitions	0.0	III. Transitions	.08
a. Power to Auto.		a. -	-	a. Power to Auto	.02
1. 0.3 V_H	0.10			1. -	-
2. 0.6 V_H	0.20			2. -	-
3. 0.9 V_H	0.05			3. -	-
b. Auto. to Power		b. -	-	b. Auto to Power	.06
1. 0.4 V_H	0.10			1. -	-
2. 0.6 V_H	0.20			2. -	-
3. 0.8 V_H	0.05			3. -	-
IV. Autorotation	3.48	IV. Autorotation	0.0	IV. Autorotation	1.92
a. Steady Forward Flight		a. -	-	a. Steady Forward Flight	.86
1. 0.4 V_H	0.80				
2. 0.6 V_H	1.00				
3. 0.8 V_H	0.20				
b. 60 Kt. Control Reversal	.	b. -	-	b. Control Reversal	.30
1. Longitudinal	0.01				
2. Lateral	0.01				
3. Rudder	0.01				
c. Right Turns		c. -	-	c. Right Turn	.20
1. 0.4 V_H	0.20				
2. 0.6 V_H	0.25				
3. 0.8 V_H	0.05				
d. Left Turns		d. -	-	d. Left Turn	.20
1. 0.4 V_H	0.20				
2. 0.6 V_H	0.25				
3. 0.8 V_H	0.05				
e. Auto. Landing Appr. W/Power Recovery IGE		e. -	-	e. -	-
1. 0.4 V_H	0.08				
2. 0.6 V_H	0.10				
3. 0.8 V_H	0.02				
f. Full Auto Landing	0.25	f. -	-	f. Auto. Landing	.30
g. -	-	g. -	-	g. Pull-Ups	.06

TABLE 40. ORIGINAL AR-56 UTILITY MISSION SPECTRUM

Condition	Percent Flight Time
Ground conditions	1.0
Takeoff	(400)
Steady hovering	10.0
Turns hovering	(1000)
Control reversals hovering	(1000)
Sideward flight	1.0
Rearward flight	0.5
Landing approach	(500)
Forward level flight:	
20% VH	5.0
40% VH	5.0
50% VH	2.0
60% VH	8.0
70% VH	10.0
80% VH	15.0
90% VH	18.0
VH	10.0
115% VH	1.0
Takeoff power climb	1.0
Full power climb	3.0
Partial power descents	(500)
Power dives	2.5
Right turns	2.5
Left turns	2.5
Control reversals	(800)
Pull-ups	(250)
Power to autorotation	(40)
Autorotation to power	(40)
Autorotation - steady	1.0
Autorotation - left turn	0.2
Autorotation - right turn	0.2
Autorotation - control reversals	0.3
Autorotation - landing	0.3
Autorotation - pull-ups	(40)
Ground-air-ground cycles	(100)
Gunnery maneuvers:	
Hovering	0.1
Dives	1.5
Dive pull-outs	0.65
Turns	
Right	1.0
Left	1.0
S	0.15

TABLE 41. ADJUSTMENTS TO AR-56 UTILITY MISSION SPECTRUM

Flight Condition	No. of Occurrences per 100 Hr	Elapsed Time (sec)	Time Per 100 Hr (sec)	Percent Flight Time
Takeoff	400	8	3200	.89
Hover turns	1000	8	8000	2.22
Hover cont. rev.	1000	3	3000	.83
Landing approach	500	15	7500	2.08
Partial pwr descent	500	15	7500	2.08
Control reversals	800	3	2400	.67
Pull-ups	250	7	1750	.49
Power to autorotation	40	2	80	.02
Autorotation to power	40	5	200	.06
Autorotation pull-ups	40	5	200	.06

The comparison of the adjusted AR-56 spectrum with the design and operational spectra indicates that the noteworthy differences between them are in the ground, level flight, and maneuver frequencies.

Although the operational spectrum does not include time for rotor starts and stops because the necessary power levels to operate the instrumentation during their occurrence were not available, its much higher ground frequency is due to the inclusion of ground idle time which is not accounted for in the design spectrum. Again, the steady-state ground time is critical in its effect on component replacement times.

TABLE 42. ADJUSTED AR-56 UTILITY SPECTRUM

Condition	Percent Flight Time
Ground conditions	1.00
Takeoff	.89
Steady hovering	6.95
Turns hovering	2.22
Control reversals hovering	.83
Sideward flight	1.00
Rearward flight	.50
Landing approach	2.08
Forward level flight:	
20% VH	3.03
40% VH	2.92
50% VH	1.00
60% VH	8.00
70% VH	10.00
80% VH	13.84
90% VH	18.00
VH	10.00
115% VH	1.00
Takeoff power climb	1.00
Full power climb	3.00
Partial power descents	2.08
Power dives	2.50
Right turns	2.50
Left turns	2.50
Control reversals	.67
Pull-ups	.49
Power to autorotation	.02
Autorotation to power	.06
Autorotation - steady	.86
Autorotation - left turn	.20
Autorotation - right turn	.20
Autorotation - control reversals	.30
Autorotation - landing	.30
Autorotation - pull-ups	.06

The lesser level flight frequency in the operational spectrum is attributed to the following: Whereas the design and AR-56 spectra were apparently based on the assumption that a utility helicopter would fly long missions with few maneuvers and excursions from the intended flight path, the SEA UH-1H with its high ascent and descent frequencies obviously hopped from one area to another with the consequent numerous takeoffs and landings, large amounts of ground time, and small amounts of level flight time. This actual performance is further substantiated by the number of GAG cycles and rotor starts and stops in 100 hours of UH-1H flight time. The 548 GAG cycles indicate that the helicopter was constantly performing takeoffs and landings, and the 52 rotor starts and stops indicate that the helicopter engine remained running while the aircraft was on the ground. In addition, since the operational spectrum lists 5 times as many GAG cycles as the AR-56 spectrum, much longer flights are anticipated in the latter spectrum than those flown in SEA.

The high collective pull-up and pushover frequencies in the operational spectrum are attributed to the similarly high frequencies of the closely related ascents and descents. The low frequency of turns in the operational spectrum was due to the inability to detect normal turns in the oscillograms without cyclic stick and rudder pedal position recordings. However, the most severe turns were accounted for since they would have been identified as unknown conditions, most of which were probably turns.

2.4 COMPARISON OF MANUFACTURER'S DESIGN AND NAVY AR-56 MISSION PROFILES WITH OPERATIONAL MISSION PROFILES EXCLUDING GROUND TIME

2.4.1 General

In the mission profile comparisons in Section 2.3, the operational mission profiles included time for virtually all ground operations including steady-state conditions which accounted for 9.4 to 40.0 percent of the total mission time, whereas the design and AR-56 profiles apparently represented ground time for only such operations as rotor starts and stops which generally accounted for only some 1 percent of the total mission time. Consequently, in this section, to more realistically compare the times for in-flight operations, all ground time was deleted from the operational mission profiles and the remaining percentages of time were normalized to 100 percent.

Except for the exclusion of the comparison for the assault helicopter (since this comparison was made in Section 2.3.5 independently of ground operations), the helicopter classes are ordered as above in the following comparisons.

2.4.2 Attack - AH-1G Helicopter

As seen in Table 43, the level flight time in the operational spectrum is still much lower than those in the other two spectra, and the times for IGE and nonfiring maneuvers in the operational spectrum are now twice as large as those in the design spectrum. These disparities substantiate the supposition that rotor starts and stops and GAG cycles are the only ground operations represented in the design and AR-56 spectra. Whereas the design spectrum includes rotor starts and stops but not GAG cycles, the AR-56 spectrum includes GAG cycles but not rotor starts and stops.

The comparison of the GAG cycles in the operational and AR-56 spectra indicates that the SEA AH-1G flew shorter missions than those anticipated in the AR-56 spectrum. GAG cycles are not listed in the design spectrum since, as stated in Reference 6, "...GAG cycles are omitted from consideration since they are of a low cycle nature and are generally accounted for by fatigue test methods and/or analysis during fatigue life substantiation." However, because of the large number of GAG cycles in the operational spectrum, they should be represented in the design spectrum.

To compare the rotor starts and stops in the operational and design spectra, a 10-second duration for each was assumed to convert their times in the design spectrum to occurrences. The resultant 180 occurrences are about twice as many as those in the operational spectrum. As cited above for the inclusion of GAG cycles in the design spectrum, the rotor starts and stops should be included in the AR-56 spectrum, since their centrifugal loads will shorten the lives of some helicopter components.

2.4.3 Crane - CH-54A Helicopter

As seen in Tables 44 and 45, the times in the ascent, descent, and maneuver segments in the operational spectrum substantiate the previous statement that the SEA CH-54A flew shorter missions than those anticipated in the design and AR-56 spectra. Also, as listed in Table 45, the approximately equal number of GAG cycles for the operational and AR-56 spectra indicates that the number of SEA CH-54A flights was nearly the same as that anticipated in the AR-56 spectrum, even though the flight distances in the two spectra differ greatly.

TABLE 43. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR AH-1G ATTACK MISSION

DESIGN SPECTRUM			OPERATIONAL SPECTRUM			AR-56 (ATTACK) SPECTRUM		
Mission Segment Basic Condition	Percentage of Flight Time		Mission Segment Basic Condition	Percentage of Flight Time		Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		1.00	I. Ground Conditions			I. Ground Conditions		1.00
a. Normal Start	0.50		a. Rotor Start	(111)		a. -		
b. Shutdown W/coll	0.50		b. Rotor Stop	(111)		b. -		
c. -	-		c.			c. Steady	1.00	
d. -	-		d.			d. GAG	(100)	
e. -	-		e. GAG	(186)				
II. IGE Maneuvers		6.65	II. IGE Maneuvers		11.53	II. IGE Maneuvers		9.47
a. Takeoff			a. Takeoff	.94		a. Takeoff		
1. Normal	0.90		1. -	-		1. Normal	.89	
2. Jump	0.10		2. -	-		2. -	-	
b. Hovering			b. Hovering			b. Hovering		
1. Steady	2.17		1. Steady	8.22		1. Steady	3.77	
2. Right Turn	0.10		2. -	-		2. Turns	.89	
3. Left Turn	0.10		3. -	-		3. -	-	
4. Control Reversal			4. Control Reversal			4. Control Reversal	.34	
Longitudinal	0.01		Longitudinal	.03		-	-	
Lateral	0.01		-	-		-	-	
Rudder	0.01		-	-		-	-	
c. Sideward Flight			c. -			c. Sideward Flight	1.00	
1. To the Right	0.25		-	-		1. -	-	
2. To the Left	0.25		-	-		2. -	-	
d. Rearward Flight	0.25		d. -	-		d. Rearward Flight	.50	
e. Acceleration			e. -	-		e. - -	-	
1. Hover to climb A/S	0.50		-	-		- -	-	
f. Deceleration			f. -	-		f. - -	-	
1. Normal	0.70		-	-		- -	-	
2. Quick Stop	0.30		-	-		- -	-	
g. Approach and Landing	1.00		g. Flare	1.90		g. Approach	2.08	
h. -	-		h. Pull-Ups	.15		h. -	-	
i. -	-		i. Pushovers	.22		i. -	-	
j. :			j. Initiation of Ascent	.07		j. -	-	

TABLE 43. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	RPM	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (ATTACK) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
III. Forward Level Flight			60.000	III. Forward Level Flight		45.43	III. Forward Level Flight		63.81
Airspeed	RPM								
a. 0.50 VH	314	0.50		a. All Airspeeds	45.43		a. .2-.5VH	5.45	
	324	4.50							
b. 0.60 VH	314	0.20		b. -	-		b. .6 VH	8.00	
	324	1.80							
c. 0.70 VH	314	0.30		c. -	-		c. .7 VH	8.00	
	324	2.70							
d. 0.80 VH	314	1.50		d. -	-		d. .8 VH	12.36	
	324	13.50							
e. 0.90 VH	314	2.50		e. -	-		e. .9 VH	15.00	
	324	22.50							
f. VH	314	1.00		f. -	-		f. VH	15.00	
	324	9.00							
IV. Nonfiring Maneuvers			19.55	IV. Nonfiring Maneuvers		41.01	IV. Nonfiring Maneuvers		16.72
a. Full Power Climb				a. Full Power Climb	.40		a. Full Power Climb		
1. Normal		4.00		1. -	-		1. Normal	3.00	
2. High-speed		1.00		2. -	-		2. High-Speed	1.00	
b. Maximum Rate Accel				b. Maximum Rate Accel	-		b. -	-	
c. Climb-Cruise A/S		2.80		c. Climb	16.00		c. -	-	
d. Normal Turns				d. Unkrown Condition	6.24		d. Normal Turns		
1. To the Right				1. -	-		1. Right	3.50	
0.5 VH		1.10		-	-		-	-	
0.7 VH		1.00		-	-		-	-	
0.9 VH		2.00		-	-		-	-	
2. To the Left				2. -	-		2. Left	3.50	
0.5 VH		1.00		-	-		-	-	
0.7 VH		1.00		-	-		-	-	
0.9 VH		2.00		-	-		-	-	
3. 0.9 VH Control Reversal				3. Control Reversal			3. Control Reversal	1.67	
Longitudinal		0.50		Longitudinal	-		-	-	
Lateral		0.05		-	-		-	-	
Rudder		0.05		-	-		-	-	

TABLE 43. (Continued)

DESIGN SPECTRUM: Misison Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM: Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (ATTACK) SPECTRUM: Mission Segment Basic Condition	Percentage of Flight Time	
e. Sideslip	0.50		e. -	-		e. -	-	
f. Part Power Descent	2.55		f. Partial Power Descent	5.27		f. Partial Power Descent	2.08	
g. -	-		g. Pull-Ups	1.64		g. Pull-Ups	.97	
h. -	-		h. Pushovers	2.45		h. -	-	
i. -	-		i. Initiation of Ascent	.39		i. -	-	
			j. Other Descents	8.62		j. Power Dives	1.00	
V. Gunnery Maneuvers		9.4	V. Gunnery Maneuvers		1.97	V. Gunnery Maneuvers		5.40
a. Firing in a Hover	0.075		a. -	-		a. -	.1[illegible]	
b. Strafing in Accel. from a Hover	0.05		b. -	-		b. -	-	
c. Gunnery Runs			c. Dives	.73		c. Dives	2.50	
1. PT. Target Dives			1. -	-		1. -	-	
To 0.6 VL	0.28		-	-		-	-	
To 0.8 VL	0.84		-	-		-	-	
To 0.9 VL	1.40		-	-		-	-	
To VL	0.28		-	-		-	-	
2. Spray Fire Dives			2. -	-		2. -	-	
To 0.6 VL	0.12		-	-		-	-	
To 0.8 VL	0.36		-	-		-	-	
To 0.9 VL	0.60		-	-		-	-	
To VL	0.12		-	-		-	-	
d. Gunnery Run Pull-Up			d. Dive Pull-Out	1.24		d. Dive Pull-Out	.65	
1. To the Right			1. -	-		1. -	-	
0.6 VL	0.10		-	-		-	-	
0.8 VL	0.30		-	-		-	-	
0.9 VL	0.50		-	-		-	-	
2. To the Left			2. -	-		2. -	-	
0.6 VL	0.10							
0.8 VL	0.30							
0.9 VL	0.50							
VL	0.10							
3. Symmetrical			3. -			3. -	-	
0.6 VL	0.01							
0.8 VL	0.03							
0.9 VL	0.05							
VL	0.01							

TABLE 43. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (ATTACK) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
e. Gunnery Turns			e. -			e. Gunnery Turns		
1. To the Right			1. -	-		1. Rt	1.00	
0.5 VH	0.375							
0.7 VH	0.375							
0.9 VH	0.75							
2. To the Left			2. -	-		2. Left	1.00	
0.5 VH	0.375							
0.7 VH	0.375							
0.9 VH	0.75							
3. S-Turns			3. -	-		3. S-Turns	.15	
At 0.8 VH	0.20							
At VH	0.075							
VI. Power Transitions		.700	VI. Power Transitions		.06	VI. Power Transitions		.20
a. Power to Auto			a. Power to Auto	.03		a. Power to Auto	.06	
1. 0.5 VH	0.05		1. -	-		1. -	-	
2. 0.7 VH	0.125		2. -	-		2. -	-	
3. 0.9 VH	0.175		3. -	-		3. -	-	
b. Auto to Power			b. Auto to Power	.03		b. Auto to Power	.14	
1. In Ground Effect	0.15		1. -	-		1. -	-	
2. 0.4 VH	0.10		2. -	-		2. -	-	
3. 0.6 VH	0.075		3. -	-		3. -	-	
4. Max Auto A/S	0.025					4. -	-	
VII. Autorotation		3.15	VII. Autorotation		.03	VII. Autorotation		3.4
a. Stabilized Flight			a. Steady	.03		a. Steady	1.06	
1. 0.4 VH	0.20		1. -	-		1. -	-	
2. 0.6 VH	1.40		2. -	-		2. -	-	
3. Max Auto A/S	0.30		3. -	-		3. -	-	
b. Auto Turns			b.	-		b. Auto Turns		
1. To the Right			1. -	-		1. Right	.50	
0.4 VH	0.05							
0.6 VH	0.40							
Max Auto A/S	0.05							
2. To the Left			2. -	-		2. Left	.50	
0.4 VH	0.05							
0.6 VH	0.40							
Max Auto A/S	0.05							
c. Auto Landing	0.25		c.	-		c. Auto Landing	.30	
d. -	-		d. Pull Ups	0.0		d. Pull-Ups	.14	
e. -	-		e. Pushovers	0.0		e. -	-	
f. -	-		f. -	-		f. Control Reversals	.30	

TABLE 44. DESIGN, OPERATIONAL, AND AR-56 MISSION SEGMENT FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR CH-54A CRANE MISSION

DESIGN SPECTRUM			OPERATIONAL SPECTRUM			AR-56 (CRANE) SPECTRUM		
Mission Segment		Percent Time	Mission Segment		Percent Time	Mission Segment		Percent Time
I.	Ground	2.11	I.	Ground	0.0	I.	Ground	1.000
II.	Hover	21.385	II.	Hover, Steady	3.97	II.	Hover	16.000
III.	Sideward and Rearward Flight	2.175	III.	-	-	III.	Sideward and Rearward Flight	1.500
IV.	Ascent	8.422	IV.	Ascent, Steady	26.89	IV.	Ascent	3.670
V.	Descent	5.270	V.	Descent, Steady	24.24	V.	Descent	5.558
VI.	Cruise	53.240	VI.	Level Flight, Steady	31.17	VI.	Cruise	61.254
VII.	Takeoff Maneuvers	.02	VII.	Takeoffs	1.18	VII.	Takeoff Maneuvers	1.550
VIII.	Maneuvers	7.328	VIII.	Maneuvers	11.69	VIII.	Maneuvers	7.708
IX.	-		IX.	Cargo Pickup	.85	IX.	-	
X.	-		X.	Cargo Drop	.26	X.	-	

TABLE 45. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR CH-54A CRANE MISSION

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (CRANE) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground		0.00	I. Ground		2.68	I. Ground		1.00
a. Rapid Increase of RPM	(238)		a. Rotor Start/Stop	(27)		a. -	-	
b. Taxi Turns	(830)		b.			b. -	-	
c. Takeoff and Climb Out	(238)		c. Takeoff	2.68		c. Takeoff	(400)	
d. -	-		d.			d. Steady	1.00	
e. -	-		e.			e. -	-	
f. -	-		f. GAG	(126)		f. GAG	(100)	
II. Hovering		16.95	II. Hovering		3.99	II. Hovering		17.50
a. Steady	16.95		a. Steady	3.97		a. Steady	16.00	
b. Reversals			b. Reversals			b. Reversals	(1000)	
1. Lateral	(475)		1. -	-		1. -	-	
2. Longitudinal	(475)		2. Longitudinal	.02		2. -	-	
3. Rudder	(475)		3. -	-		3. -	-	
c. Left Sideward	(142)		c. -	-		c. Sideward	1.00	
d. Right Sideward	(142)		d. -	-		d. -	-	
e. Rearward	(142)		e. -	-		e. Rearward	.50	
f. Hovering Turns			f. -	-		f. Hovering Turns	(1000)	
1. Left	(120)					1. -	-	
2. Right	(120)					2. -	-	
III. Forward Flight		58.01	III. Forward Flight		93.31	III. Forward Flight		81.5
a. Climb	(238)		a. -			a. Takeoff Power Climb	3.00	
b. -	-		b. Full Power Climb	.20		b. Full Power Climb	4.00	
c. -	-		c. Other Ascents	26.69		c. -	-	
d. Level Flight	52.97		d. Level Flight	31.17		d. Level Flight	65.00	
e. Right Turns	2.40		e. Unknown	.02		e. Right Turn	2.50	
f. Left Turns	2.40		f. -	-		f. Left Turn	2.50	
g. Power to Auto	(20)		g. -	-		g. Power to Auto	(40)	
h. Steady Auto	.24		h. -	-		h. Steady Auto	2.0	
i. Auto to Power	(20)		i. -	-		i. Auto to Power	(40)	
j. Partial Power Descent	(75)		j. Partial Power Descent	9.25		j. Partial Power Descent	(500)	
k.	-		k. Other Descents	15.00		k. Power Dives	2.50	

TABLE 45. (Concluded)

DESIGN SPECTRUM		OPERATIONAL SPECTRUM		AR-56 (CRANE) SPECTRUM	
Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time	Mission Segment Basic Condition	Percentage of Flight Time
l. Symmetrical Pull-Outs	(475)	l. Pull-Ups	3.09	l. Pull-Ups	(290)
m. -	-	m. Pushovers	4.60	m. -	-
n. Control Reversals	(950)	n. -	-	n. Control Reversals	(800)
o. Landing Approach	(119)	o. Flare	2.18	o. Landing Approach	(500)
p. Hover Approach	(119)	p. -	-	p. -	-
q. -	-	q. Cargo Pickup	.85	q. -	-
r. -	-	r. Cargo Drop	.26	r. -	-

If the "rapid increase of rpm" flight condition listed in the design spectrum is assumed to be equivalent to rotor starts, the design spectrum anticipates 9 times as many rotor starts as occurred in the operational spectrum. However, if this flight condition is assumed to represent rotor starts and rapid changes of rotor speed from ground to in-flight levels, and if these rotor occurrences are compared with the rotor starts, GAG cycles, and transient flight conditions in the operational spectrum, the two groups of data are nearly equal. Therefore, the design spectrum should include GAG cycles, and the operational spectrum should represent rapid changes of rotor speed. In addition, as stated above, the AR-56 spectrum should include rotor starts and stops as well as GAG cycles.

2.4.4 Observation - OH-6A Helicopter

Table 46 indicates that the maneuvers (pull-ups, pushovers, etc.) and GAG cycles in the operational spectrum occurred more frequently than anticipated in the other two spectra. As stated previously, the high rate of maneuvers in the SEA OH-6A data was due to the NOE flying. The GAG cycles in the operational spectrum occurred twice as frequently as those anticipated in the AR-56 spectrum.

With the times for the rotor starts and stops in the design spectrum converted to occurrences by assuming 10-second durations, the resultant 90 occurrences compare closely with the 78 rotor starts and stops in the operational spectrum.

2.4.5 Transport - CH-47A Helicopter

In Table 47, the total maneuver time in the operational spectrum is now nearly equal to that in the design spectrum, but the ascent, descent, and level flight times in the two spectra differ considerably. Although the total maneuver times for the three spectra closely agree, the types of maneuvers in the respective spectra differ greatly: Whereas the maneuvers in the design and AR-56 spectra are mostly turns and hovers, those in the operational spectrum consist mainly of pull-ups and pushovers.

The comparison of the GAG cycles in the operational and AR-56 spectra indicates that the SEA CH-47A made more landings than anticipated in the AR-56 spectrum. Again assuming a 10-second duration for each rotor start and stop but using it to convert occurrences in the operational spectrum to percentage of time, the resultant 0.56 percent of the total flight time compares closely with the time in the design spectrum but not in the AR-56 spectrum.

TABLE 46. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR OH-6A OBSERVATION MISSION

DESIGN SPECTRUM

Mission Segment Basic Condition	Percentage of Occurrence	
I. Ascent		6.5
a. Maximum performance takeoff	0.50	
b. Climb (takeoff power)	2.00	
Climb (maximum continuous power)	4.0	
II. Maneuver		16.6
a. Longitudinal, lateral and Pedal Reversal, Hover	1.50	
b. Turn, Hover	-	
c. Right Turns, 30, 60, 90% V_{NE}	3.00	
Left Turns, 30, 60, 90% V_{NE}	3.00	
d. Autorotation Entry - 30, 60, 90% V_{NE}	1.50	
e. Pull-Up	1.00	
f. Longitudinal, Lateral and Pedal Reversal	1.50	
g. Simulated Power Failure	0.10	
h. Pushover	-	
i. Power Recovery from Autorotation	0.50	

OPERATIONAL SPECTRUM

Mission Segment Basic Condition	Percentage of Occurrence	
I. Ascent	.67	11.42
a. Takeoff	.51	
b. Climb (takeoff power)	-	
Climb (full power)	2.27	
Climb (other)	8.48	
II. Maneuver		33.90
a. Longitudinal Reversal Hover	.04	
b. -	-	
c. -	-	
d. -	-	
e. Pull-Up Collective	10.57	
Cyclic	.14	
f. Longitudinal Reversal	.31	
g. -	-	
h. Pushover Collective	8.84	
Cyclic	.95	
i. -	-	

AR-56 (UTILITY) SPECTRUM

Mission Segment Basic Condition	Percentage of Occurrence	
I. Ascent		4.5
a. Takeoff	0.98	
b. Climb (takeoff power)	0.88	
Climb (full power)	2.64	
II. Maneuver		8.08
a. Control Reversal Hover	0.73	
b. Turn, Hover	1.47	
c. Right Turn	2.20	
Left Turn	2.20	
d. Autorotation Entry	0.03	
e. Pull-Up	0.18	
f. Control Reversal	0.59	
g. -	-	
h. -	-	
i. Power Recovery from Autorotation	0.03	

TABLE 46. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence		AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence	
j. Right Turns at 30, 60, 90° VNE Autorotation	1.00		i.			j. Right Turn, Autorotation	0.18	
Left Turns at 30, 60, 90° VNE Autorotation	1.00					Left Turn, Autorotation	0.18	
k. Longitudinal, Lateral and Pedal Reversal Autorotation	1.50		k.	-		k. Control Reversal Autorotation	0.26	
l. Pull-Up, Autorotation	1.00		l.			l. Pull-Up, Autorotation	0.03	
m. -	-		m. Initiation of Ascent	.65		m. -	-	
n. -	-		n. Unknown Condition	12.38		n. -	-	
III. Descent		7.00	III. Descent		9.17	III. Descent		8.21
a. Partial Power Descent	2.00		a. Partial Power Descent	.25		a. Partial Power Descent	4.89	
b. Rapid Transition and Flare	3.00		b. Flare	.84		b. Landing Approach	3.06	
Approach to Hover	-							
c. -	-		c. Other Descents	8.09		c. -	-	
d. Autorotation Landing, Including Approach and Flare	2.00		d.			d. Autorotation Landing	0.26	
IV. Steady State		69.90	IV. Steady State		45.42	IV. Steady State		79.21
a. -	-		a. Ground Conditions	.00		a. Ground Conditions	0.88	
b. Hover, In Ground Effect (IGE)	0.50		b. Hover (IGE)	3.74		b. Hover	3.80	
Hover, Out of Ground Effect (OGE)	-							

TABLE 46. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence	OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence	AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Occurrence
c. Level Flight at 20% V_{NL}	1.00	c. Level Flight	27.65	c. 20% V_H	4.40
Level Flight at 40% V_{NL}	3.00			40% V_H	4.40
Level Flight at 60% V_{NL}	18.00			50% V_H	1.76
Level Flight at 80% V_{NL}	25.30			60% V_H	7.04
V_H	15.00			70% V_H	8.80
V_{NL}	3.00			80% V_H	13.20
111% V_{NL}	0.60			90% V_H	15.85
				V_{NE}	8.80
				115% V_H	0.88
				Power Dives	2.20
d. Sideward Flight	0.50	d. -	-	d. Sideward Flight	0.88
Rearward Flight	0.50			Rearward Flight	0.44
e. Autorotation	2.00	e. -	-	e. Autorotation	0.88
f. -	-	f. IGE Maneuver	14.03	f. -	-
g. Rotor Start	.25	g. Rotor Start	(78)	g. -	-
h. Rotor Stop	.25	h. Rotor Stop	(78)	h. -	-
i. -	-	i. GAG	(228)	i. GAG	(100)

TABLE 47. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR CH-47A TRANSPORT MISSION

DESIGN SPECTRUM

Mission Segment	Basic Condition	Percentage of Flight Time	
I.	Steady Level Segment		80.0
	a. Hover	10.0	
	b. Transition	10.0	
	c. .9 V_h	50.0	
	d. 1.0 V_h	10.0	
II.	Steady Ascent		6.0
	a. Climb	-	
	1. Full Power	6.0	
	2. Takeoff Power	0.0	
	3. -	-	
III.	Steady Descent		4.0
	a. Partial Power	-	
	b. Autorotation	4.0	
	c. Dive	-	
	d. -	-	
IV.	Maneuver		10.0
	a. Ground Condition		
	1. Rotor Start	.5	
	2. Taxi	.5	
	3. -	-	
	4. -	-	
	5. -	-	
	b. Takeoff	.5	
	c. Sideward Flight	.5	
	d. Rearward Flight	.5	
	e. Symmetric Maneuvers		
	1. Pull-Up 1.4 g	.5	
	2. Auto Pull-Up	.5	
	3. Change to PPD	.5	
	4. -	-	
	5.	-	
	6. -	-	

OPERATIONAL SPECTRUM

Mission Segment	Basic Condition	Percentage of Flight Time	
I.	Steady Level		38.17
	a. Hover	7.75	
	b. Transition	-	
	c. Level Flight	30.42	
	d. -	-	
II.	Steady Ascent		26.34
	a. Climb		
	1. Full Power	-	
	2. Takeoff Power	-	
	3. Other	26.34	
III.	Steady Descent		23.94
	a. Partial Power	21.37	
	b. Autorotation	.05	
	c. -	-	
	d. Other	2.52	
IV.	Maneuver		11.37
	a. Ground Condition		
	1. Start/Stop	(410)	
	2. Taxi		
	3. Steady		
	4. Transient		
	5. GAG	(275)	
	b. Takeoff	2.45	
	c. -	-	
	d. -	-	
	e. Symmetric Maneuvers		
	1. Pull-Ups	2.40	
	2. -		
	3. -		
	4. Pushovers	2.85	
	5. Power to Auto	.05	
	6. Auto to Power	.02	

AR-56 (CARGO) SPECTRUM

Mission Segment	Basic Condition	Percentage of Flight Time	
I.	Steady Level		73.90
	a. Hover	10.50	
	b. -	-	
	c. Level Flight	63.40	
	d. -	-	
II.	Steady Ascent		3.60
	a. Climb		
	1. Full Power	2.70	
	2. Takeoff Power	.90	
	3. -	-	
III.	Steady Descent		6.40
	a. Partial Power	3.30	
	b. Autorotation	.90	
	c. Dive	2.20	
	d. -	-	
IV.	Maneuver		16.10
	a. Ground Condition		
	1. Rotor Start	.90	
	2. -	-	
	3. -	-	
	4. -	-	
	5. GAG	.50(100)	
	b. Takeoff	.50	
	c. Sideward Flight	.90	
	d. Rearward Flight	.40	
	e. Symmetric Maneuvers		
	1. Pull-Up 1.4g	.40	
	2. Auto Pull-Up	.20	
	3. -	-	
	4. -	-	
	5. Power to Auto	.10	
	6. -	-	

TABLE 47. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	AR-56 (CARGO) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time
f. Turns		f. Unknown	.10	f. Turns	
1. Hover	1.5			1. Hover	2.40
2. Left Level	1.5			2. Left Level	2.20
3. Right Level	1.5			3. Right Level	2.20
4. Left Descending	.5			4. Left Descending	.20
5. Right Descending	.5			5. Right Descending	.20
g. Control Reversals	-	g. Control Reversals		g. Control Reversals	
		1. Longitudinal	.13	1. Hovering and Flight	1.50
h. Yawing	.5	h. Yawing	-	h. -	-
i. Landing		i. Landing		i. Landing	
1. Flare	1.0	1. Flare	3.18	1. Approach	3.20
2. Autorotation to Ldg.	.5	2. -		2. Autorotation to Landing	.30
j. -	-	j. Cargo Pickup	.12	j. -	-
k. -	-	k. Cargo Drop	.07	k. -	-

2.4.6 Utility - UH-1H Helicopter

The same trends observed in the previous comparison of the utility spectra with the operational spectrum including ground time still prevail in Table 48. However, the time for the unknown condition in the operational spectrum now compares more closely with the times for turns in both of the other two spectra.

While the design spectrum reflects 180 rotor starts and stops, which were obtained by assuming the 10-second duration for each and then converting time to occurrences, the operational spectrum has 52 such occurrences. Since the UH-1H engine was not normally shut down at remote sites and since the operational spectrum has 548 GAG cycles, the SEA UH-1H landed frequently without shutting down. Therefore, the 180 rotor stops in the design spectrum appears high, and the 100 GAG cycles in the AR-56 spectrum appears low.

2.5 MISSION PROFILES FOR FUTURE HELICOPTERS

2.5.1 Introduction

As presented in this section, the mission profiles for future helicopters in each of the foregoing helicopter classes are based primarily on the SEA operational mission profiles, the mission requirements of both current helicopters and advanced helicopters with their higher performance and maneuver capabilities, literature reviews, and interviews with pilots proficient in current and advanced tactics.

When the SEA data was recorded, the lines of defense were seldom clearly defined, and a potentially hostile small arms fire environment prevailed most of the time. The instrumented helicopters usually cruised at altitudes beyond the range of small arms fire and hovered minimally when operating near the ground. Attack helicopters initially used fixed-wing fighter tactics during weapon deliveries, but later when the enemy introduced surface-to-air missiles (SAM's), all helicopters flew low-level, high-speed missions.

As defined in the following paragraphs, the intensity of warfare operation will determine the flight tactics and techniques to be employed and consequently the helicopter operational requirements.

Future helicopters will perform low-intensity operations against predominantly personnel and materiel targets where enemy defenses will normally consist of small arms, crew-operated automatic weapons, and infrequent radar-controlled air defense weapons. Such operations will place only minor restrictions on the helicopters.

TABLE 48. DESIGN, OPERATIONAL, AND AR-56 FLIGHT CONDITION FREQUENCY SPECTRA WITH GROUND TIME EXCLUDED FOR UH-1H UTILITY MISSION

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time		AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	
I. Ground Conditions		1.00	I. Ground Conditions			I. Ground Conditions		1.00
a. Normal Rotor Start	0.50		a. Rotor Start	(52)		a. -	-	
b. Normal Shutdown	0.50		b. Rotor Stop	(52)		b. -	-	
c. -	-		c. Steady			c. Steady	1.00	
d. -			d. Transient			d. -	-	
e. -	-		e. Taxi			e. -	-	
f. -	-		f. GAG	(548)		f. GAG	(100)	
II. Power-on Flight		94.82	II. Power-on Flight		100.00	II. Power-on Flight		97.00
a. Vertical Take off	0.40		a. Takeoffs	1.83		a. Takeoff	.89	
b. Hovering IGE			b. IGE Hover			b. Hover		
1. Steady	3.29		1. Steady	9.02		1. Steady	6.95	
2. Right Turn	0.10					2. Turns	2.22	
3. Left Turn	0.10					3. -	-	
4. Control Reversal						4. Control Reversal	.83	
a. Longitudinal	0.01					-	-	
b. Lateral	0.01					-	-	
c. Rudder	0.01					-	-	
c. Normal Acceleration	1.00		c. -	-		c. -	-	
d. Normal Deceleration	1.00		d. -	-		d. -	-	
e. Max Rate Accel.	0.25		e. -	-		e. -	-	
f. Max Rate Decel.	0.25		f. -	-		f. -	-	
g. Sideward Flight			g. -	-		g. Sideward Flight	1.00	
1. To the Right	0.25							
2. To the Left	0.25							
h. Rearward Flight	0.25		h. -	-		h. Rearward Flight	.50	
i. Full Power Climb	4.00		i. Full Power Climb	.51		i. Full Power Climb	3.00	
j. Forward Level Flight			j. Level Flight, Steady	31.39		j. Forward Level Flight		
1. 0.2 Vne	1.00					1. .2	3.03	
2. 0.3	1.00					2. -	-	
3. 0.4	2.00					3. .4	2.92	
4. 0.5	3.00					4. .5	1.00	
5. 0.6	7.00					5. .6	8.00	
6. 0.7	8.00					6. .7	10.00	
7. 0.8	15.00					7. .8	13.84	
8. 0.9 Vne	25.00					8. .9	18.00	
9. Vne	15.00					9. VH	10.00	

TABLE 48. (Continued)

DESIGN SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	OPERATIONAL SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time	AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	Percentage of Flight Time
k. Part-Power Descent	1.00	k. Partial Power Descent	6.74	k. Partial-Power Descent	2.08
l. Right Turns		l. Unknowns	2.07	l. Right Turns	2.5
1. 0.3 V_H	0.50			1. -	-
2. 0.6 V_H	1.00			2. -	-
3. 0.9 V_H	0.50			3. -	-
m. Left Turns		m. -		m. Left Turns	2.5
1. 0.3 V_H	0.50			1. -	-
2. 0.6 V_H	1.00			2. -	-
3. 0.9 V_H	0.50			3. -	-
n. Cyclic Pull-Ups		n. Cyclic Pull-Ups		n. Pull-Ups	.49
1. 0.6 V_H	0.20			1. -	-
2. 0.9 V_H	0.05			2. -	-
o. Collective Pull-Ups		o. Collective Pull-Ups	2.60	o. -	-
1. 0.6 V_H	0.20				
2. 0.9 V_H	0.05				
p. 0.9 V_H Control Reversal		p. Control Reversal	-	p. Control Reversals	.67
1. Longitudinal	0.05	1. Longitudinal	-	1. -	-
2. Lateral	0.05			2. -	-
3. Rudder	0.05			3. -	-
q. Normal Landing		q. -	-	q. -	-
1. 6500 lb Gross Weight	0.10				
2. 7500 lb Gross Weight	0.30				
3. 8500 lb Gross Weight	0.45				
4. 9500 lb Gross Weight	0.15				
r. -	-	r. Collective Push-overs	3.90	r. -	-
s. -	-	s. Descent	12.28	s. -	-
t. -	-	t. Ascent	26.12	t. Takeoff Power Climb	1 0
u. -	-	u. Initiation of Ascent	.59	u. -	-
v. -	-	v. Flare	2.94	v. Landing Approach	2.08
w. -	-	w. -	-	w. Power Dives	3.5

TABLE 48. (Concluded)

DESIGN SPECTRUM Mission Segment Basic Condition	DESIGN SPECTRUM Percentage of Flight Time		OPERATIONAL SPECTRUM Mission Segment Basic Condition	OPERATIONAL SPECTRUM Percentage of Flight Time		AR-56 (UTILITY) SPECTRUM Mission Segment Basic Condition	AR-56 (UTILITY) SPECTRUM Percentage of Flight Time	
III. Transitions		.700	III. Transitions		0.0	III. Transitions		.08
a. Power to Auto.			a.	-		a. Power to Auto	.02	
1. 0.3 V_H	0.10					1. -	-	
2. 0.6 V_H	0.20					2. -	-	
3. 0.9 V_H	0.05					3. -	-	
b. Auto. to Power			b.	-		b. Auto to Power	.06	
1. 0.4 V_H	0.10					1. -	-	
2. 0.6 V_H	0.20					2. -	-	
3. 0.8 V_H	0.05					3.	-	
IV. Autorotation		3.48	IV. Autorotation		0.0	IV. Autorotation		1.92
a. Steady Forward Flight			a.	-		a. Steady Forward Flight	.86	
1. 0.4 V_H	0.80							
2. 0.6 V_H	1.00							
3. 0.8 V_H	0.20							
b. 60 Kt. Control Reversal			b.	-		b. Control Reversal	.30	
1. Longitudinal	0.01							
2. Lateral	0.01							
3. Rudder	0.01							
c. Right Turns			c.	-		c. Right Turn	.20	
1. 0.4 V_H	0.20							
2. 0.6 V_H	0.25							
3. 0.8 V_H	0.05							
d. Left Turns			d.	-		d. Left Turn	.20	
1. 0.4 V_H	0.20							
2. 0.6 V_H	0.25							
3. 0.8 V_H	0.05							
e. Auto. Landing Appr. w/Power Recovery IGE			e.	-		e. -	-	
1. 0.4 V_H	0.08							
2. 0.6 V_H	0.10							
3. 0.8 V_H	0.02							
f. Full Auto. Landing	0.25		f.	-		f. Auto. Landing	.30	
g. -			g.	-		g. Pull Ups	.06	

Midintensity operations will be performed by helicopters in an extensive enemy air defense and tactical air threat environment. At high altitudes, the enemy air defense will consist of radar-controlled weapons and SAM's which will force the helicopters to fly nap-of-the-earth to avoid radar detection. At low altitudes, the enemy air defense will consist of individual- and crew-operated weapons and shoulder-fired antiaircraft missiles which will cause helicopters to use dead-reckoning navigation in flying routes previously reconnoitered by scout aircraft. With at least air parity, the enemy tactical air threat will consist of VSTOL, STOL, and high-performance aircraft.

High-intensity operations will be performed by helicopters in an environment including nuclear weapons as well as the foregoing threats. In such an environment, the air cavalry attack units will have limited maneuverability and will fly with the maximum amount of flight formation dispersion that would still be consistent with command and control requirements.

In summary, to avoid enemy radar detection, radar-guided advanced automatic weapons, and other sophisticated air defense type of networks while still remaining effective as a combat force, attack and scout helicopters will have to fly NOE at high airspeeds with maximum n_z turns and hover or fly slowly among trees and obstacles as well as hover out of ground effect (HOGE).

In the order of the helicopter classes listed in Table 1, the following sections present the mission profiles of future helicopters. Since the helicopters of each class will occasionally perform the operations characteristic of other classes, some mixture of the profiles should also be considered for realistic representations. Moreover, although these profiles are reasonable conjectures, they are nevertheless tentative because of the limited data base and therefore should not be considered as representing official Army criteria.

The development of the mission profiles for the future helicopters was based on the rationale of (1) reflecting actual operational usage, (2) presenting the usage data in a format best suited for design criteria and fatigue analysis, and (3) providing uniform and standardized usage data to permit ready comparison of the data for one helicopter class with the data for each of the other classes. Accordingly, each of the following mission profiles is based on and compared with the corresponding operational mission profile presented in Section 2.2. With all data normalized to 100 hours of mission time, each mission profile consists of the following in the given order:

(1) A tabular spectrum of mission segment-flight condition frequency (expressed as either the percentage of total mission time that the helicopter performs a given flight condition in a mission segment or the number of the flight condition occurrences in a mission segment per unit time).

(2) A histogram of the airspeed frequency distribution.

(3) An exceedance curve type of cumulative maneuver n_z distribution.

(4) A table of the percentage of mission time for maneuver n_z's outside the n_z threshold.

(5) A histogram of the landing impact occurrences with Δn_z's outside the Δn_z threshold per unit time.

(6) An exceedance curve type of cumulative taxi Δn_z distribution.

2.5.2 Attack Helicopters

2.5.2.1 General

Of all the helicopter classes, the advanced attack helicopter (AAH) will have the most significant changes in performance capability and mission requirements. Generally, this helicopter will provide a stable manned aerial weapons platform for attacking ground targets. On warm days it will hover below enemy radar but out of ground effect to provide a stationary platform at maximum standoff distances. It will be capable of performing sideward flight approaching 30 knots to escape enemy acquisition without shortening the range to the target or exposing its side, which is not possible with forward flight.

In the combat scenario the attack helicopter will first be deployed to a forward holding area to await a call to action. En route to the holding area, the helicopter will follow paths that avoid enemy detection and fly NOE techniques at airspeeds below 60 knots. In the holding area the aircraft will remain in low orbit or on the ground with engines running until it advances to the assault position, again using NOE techniques and then slowing to a hover. After moving to the firing position while maneuvering between trees and obstacles at hover or airspeeds below 15 knots, it will pop up to acquire a target and then initiate missile and/or gun firing. The helicopter will then fly sideward so that the pilot and gunner may maintain line-of-sight contact with the enemy. After the firing, the helicopter will drop behind masking terrain and fly NOE out of range of the enemy weapons.

The following paragraphs discuss the AAH mission profile as represented in Figures 28 through 31 and in Tables 49 and 50.

2.5.2.2 Mission Segments

2.5.2.2.1 Ground Operations

The SEA AH-1G usually did not hover out of ground effect (HOGE) since the ambient conditions caused the aircraft to operate near the transmission limits frequently;[1,6] therefore, the additional power required to HOGE was not available. Thus, the AH-1G would wait on the ground with engines running while it was in a holding position. The AAH, however, must be capable of hovering at a 4000-foot density altitude on a 95°F day and of vertically climbing at 500 feet per minute from this position (as stated by an aviation journal[14] and during personal discussions with Lt. Colonel Rumney and Captain Herndon, both of the Cavalry and Aviation Systems Division in the Directorate of Combat Development at Fort Knox, Kentucky). Therefore, since the AAH will have a HOGE capability, it will likely spend less time on the ground.

2.5.2.2.2 Hover

Unlike the SEA AH-1G, the AAH will spend a significantly higher percentage of flight time in the hover segment, particularly in the holding area and at the assault and the firing positions where hovering in ground effect and out of ground effect will be the dominant mode of operation. In addition, the collective, lateral, and longitudinal cyclic maneuvers will increase, and rudder turns during hover or slow flight will be common.

2.5.2.2.3 Ascent and Descent

Because of the NOE techniques to be employed, the AAH will spend less time in ascent and descent, and each of these segments will have more cyclic and collective pull-ups and pushovers.

2.5.2.2.4 Level Flight

Although the AAH will have a smaller percentage of time in level flight because of the NOE flying, it will have more pull-ups and pushovers during this segment.

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[14] AVIATION WEEK AND SPACE TECHNOLOGY, March 22, 1973, p 51.

TABLE 49. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE ATTACK HELICOPTERS

Mission Segment / Flight Condition	Frequency*	
Ground Operations		12
Rotor Start	(52)	
Steady State, minimum	.85	
Steady State, average	1.66	
Steady State, maximum	5.04	
Transient	4.45	
Rotor Stop	(52)	
Hover		15
Steady State, minimum	.63	
Steady State, average	1.84	
Steady State, maximum	2.67	
Takeoff	2.81	
Collective Pull-Up	2.00	
Collective Pushover	2.00	
Touchdown	(712)	
Longitudinal Reversal	.60	
Lateral Reversal	.60	
Initiation of Ascent	.35	
Rudder Turn	1.50	
Ascent		10
Steady State, minimum	.51	
Steady State, average	1.51	
Steady State, maximum	2.02	
Takeoff	.03	
Collective Pull-Up	.75	
Collective Pushover	.50	
Cyclic Pull-Up	.50	
Cyclic Pushover	.50	
Longitudinal Reversal	.05	
Lateral Reversal	.05	
Initiation of Ascent	.13	
Mission Segment Change without maneuver	(370)	
Left Turn	1.50	
Right Turn	1.45	
Dive Pull-Out	.50	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentages of total mission time.

TABLE 49. (Continued)

Level Flight		10
Steady State, minimum	.35	
Steady State, average	.85	
Steady State, maximum	2.66	
Collective Pull-Up	.75	
Collective Pushover	.75	
Cyclic Pull-Up	.70	
Cyclic Pushover	.70	
Mission Segment Change without maneuver	(78)	
Left Turn	1.62	
Right Turn	1.62	
Descent		13
Steady State, minimum	.50	
Steady State, average	1.19	
Steady State, maximum	2.00	
Collective Pull-Up	.72	
Collective Pushover	.47	
Dive	.99	
Cyclic Pushover	.18	
Flare	.33	
Touchdown	(12)	
Mission Segment Change without maneuver	(266)	
Right Turn	3.62	
Left Turn	3.00	
I.G.E. Maneuver		29
Steady State, minimum	1.00	
Steady State, average	2.50	
Steady State, maximum	5.50	
Collective Pull-Up	2.50	
Collective Pushover	2.50	
Cyclic Pull-Up	2.50	
Cyclic Pushover	2.50	
Longitudinal Reversal	.50	
Lateral Reversal	.50	
Mission Segment Change without maneuver	(49)	
Left Turn	4.50	
Right Turn	4.50	

TABLE 49. (Concluded)

Full Power Climb		7
Steady State	1.45	
Collective Pull-Up	.38	
Collective Pushover	.38	
Cyclic Pull-Up	.40	
Cyclic Pushover	.40	
Longitudinal Reversal	.30	
Lateral Reversal	.30	
Initiation of Ascent	2.39	
Mission Segment Change without maneuver	(84)	
Left Turn	.50	
Right Turn	.50	
Partial Power Descent		
Steady State, minimum	.50	
Steady State, average	.75	
Steady State, maximum	1.32	
Collective Pull-Up	.01	
Collective Pushover	.01	
Flare	.01	
Mission Segment Change without maneuver	(1)	
Left Turn	.70	
Right Turn	.70	

TABLE 50. PERCENTAGE OF ATTACK MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA AH-1G (%)	Future A/C (%)
Ascent	5.25	10.15
Level Flight	1.46	2.18
Descent	2.31	4.76
I.G.E. Maneuver	5.64	15.18
Partial Power Descent	1.92	2.96

2.5.2.2.5 In Ground Effect

Whereas the SEA AH-1G spent very little time near the ground because of its high-speed fighter-type diving tactics, the AAH will spend much time in ground effect because of the tactics planned for low-, mid-, and high-intensity warfare operations (as stated in Reference 14 and during the personal discussions with Lt. Colonel Rumney and Captain Herndon).

2.5.2.2.6 Full Power Climb (Intermediate Power Climb)

The AAH will have a considerably greater percentage of time in this segment, which will include NOE flying and pop-up maneuvers.

2.5.2.2.7 Takeoff Power Climb

Because of its greater power, the AAH will likely use an intermediate power climb, rather than a takeoff power climb, except in hot environments.

2.5.2.3 Airspeeds

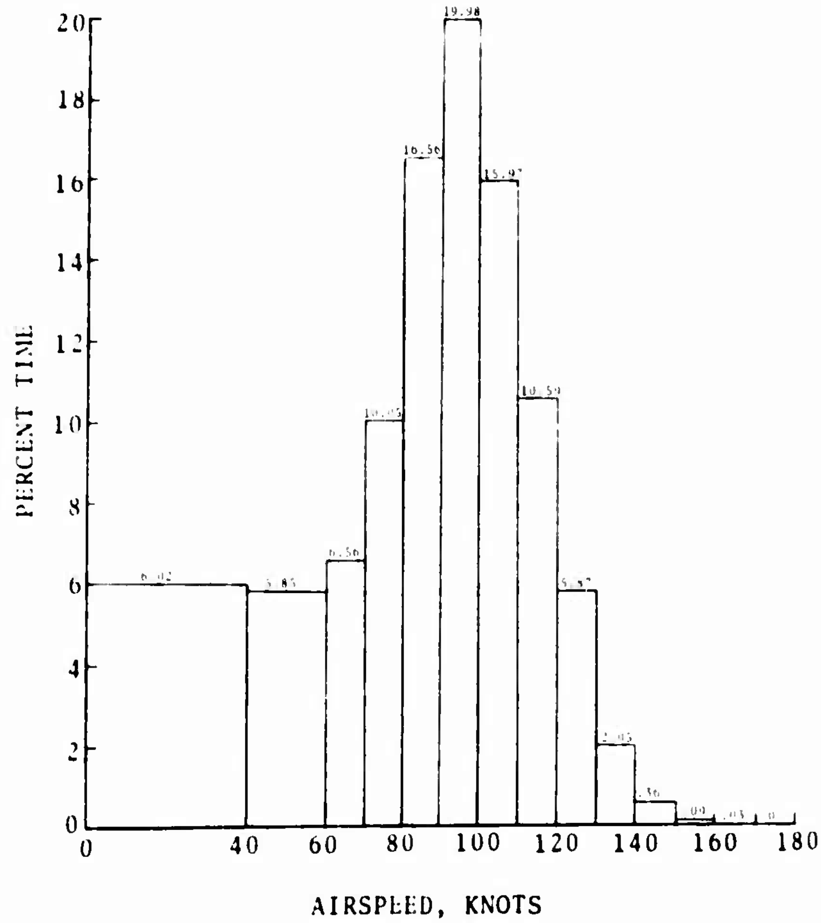
Because of NOE flying techniques to be employed, both at low speeds (0 to 15 knots) and intermediate speeds (80 to 100 knots), the percentages of time in airspeed ranges for the AAH will change considerably from those for the SEA AH-1G. Figure 28 compares the percentages for the SEA AH-1G with those expected for the AAH.

2.5.2.4 Normal Load Factors

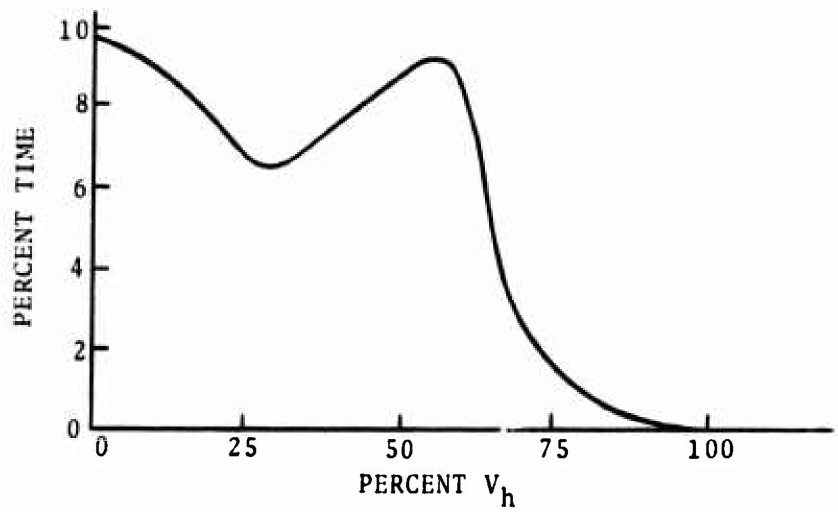
2.5.2.4.1 Maneuver

Although the amplitudes of maneuver n_z's will not be higher in the AAH operation, they will vary with the type of maneuver. For example, the amplitudes during a pop-up from hover in the AAH performance will be appreciably greater than those recorded in the SEA AH-1G operation, but those in the AAH pull-outs will be smaller than those in the SEA operation since the AAH will not perform dives as such in the mid-to-high intensity warfare operations.

Table 50 compares the percentage of time that the SEA AH-1G had maneuver n_z's outside the n_z threshold with that estimated for the AAH, and Figure 29 compares the cumulative maneuver n_z distributions for the two aircraft.



a. Operational Mission Profile



b. Future Mission Profile

Figure 28. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Attack Helicopters.

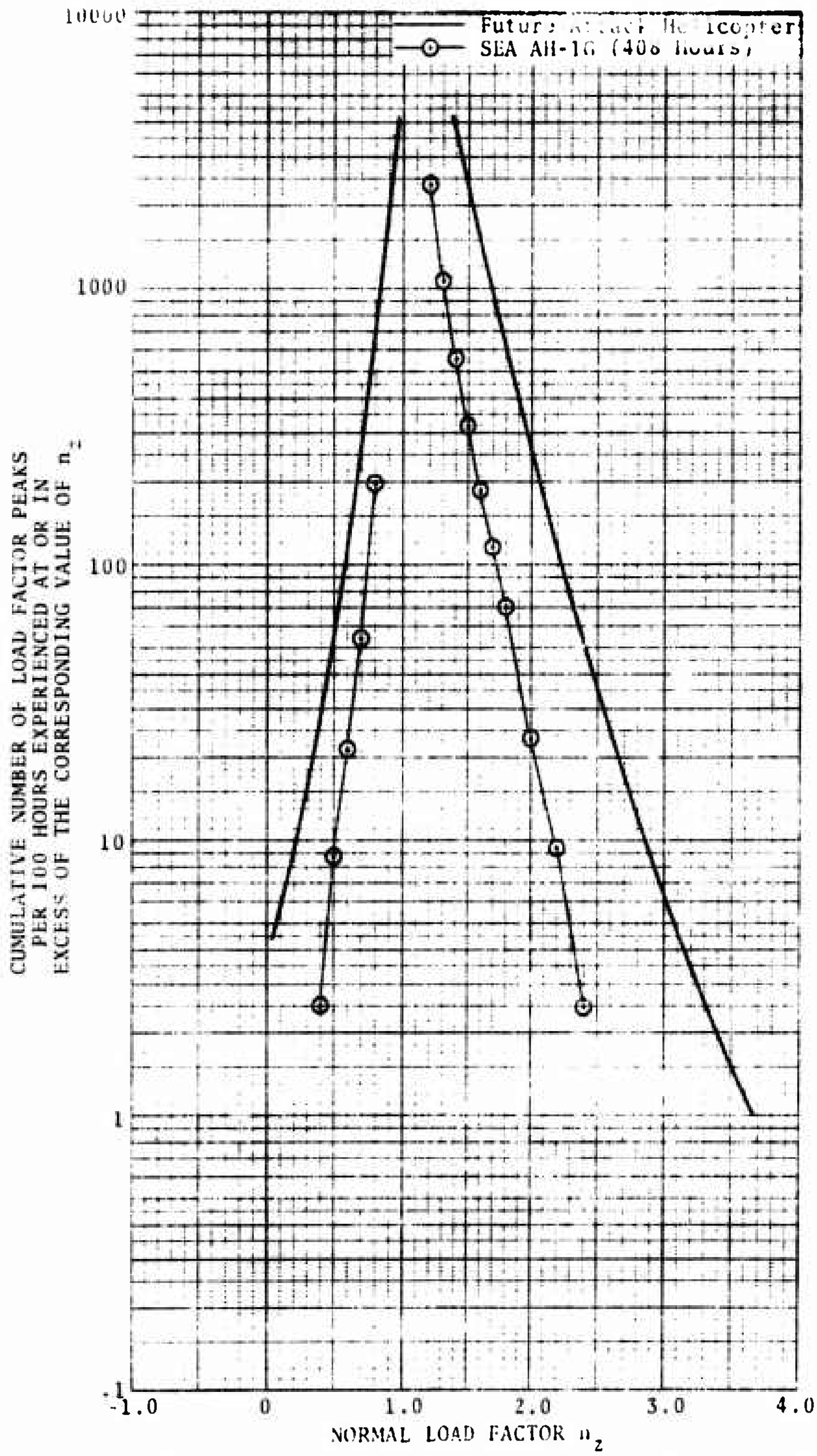


Figure 29. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Attack Helicopter.

2.5.2.4.2 Landing Impact and Taxi

Under normal operating conditions the landing impact and taxi Δn_z's of the AAH will generally be the same as those experienced in SEA. During intense warfare, however, the likelihood of hard landings increases. Such landings may occur when the aircraft has a large gross weight. Consequently, the Δn_z distribution in Figure 30 has higher values for the AAH than for the SEA AH-1G. In addition, Figure 31 presents the cumulative taxi Δn_z distributions for both aircraft.

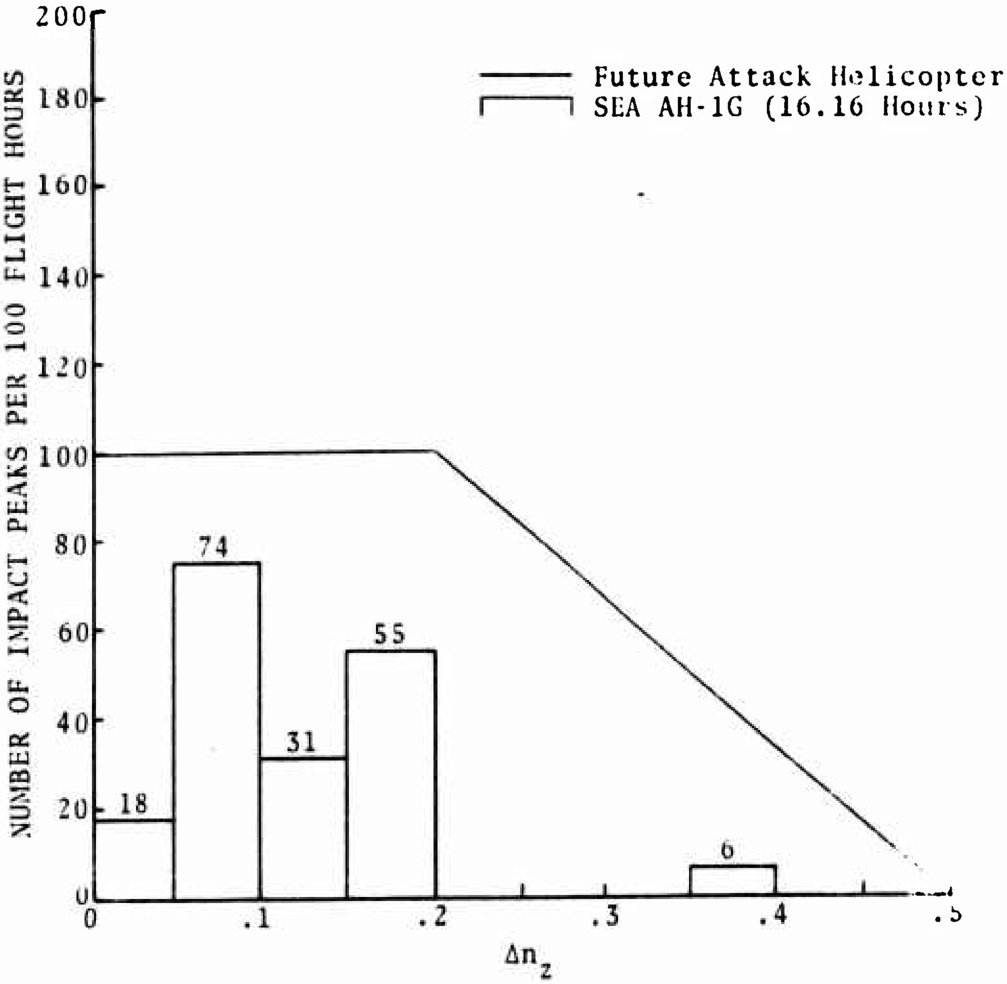


Figure 30. Landing Impact Peak Distribution of the Operational and Future Mission Profile for the Attack Helicopter.

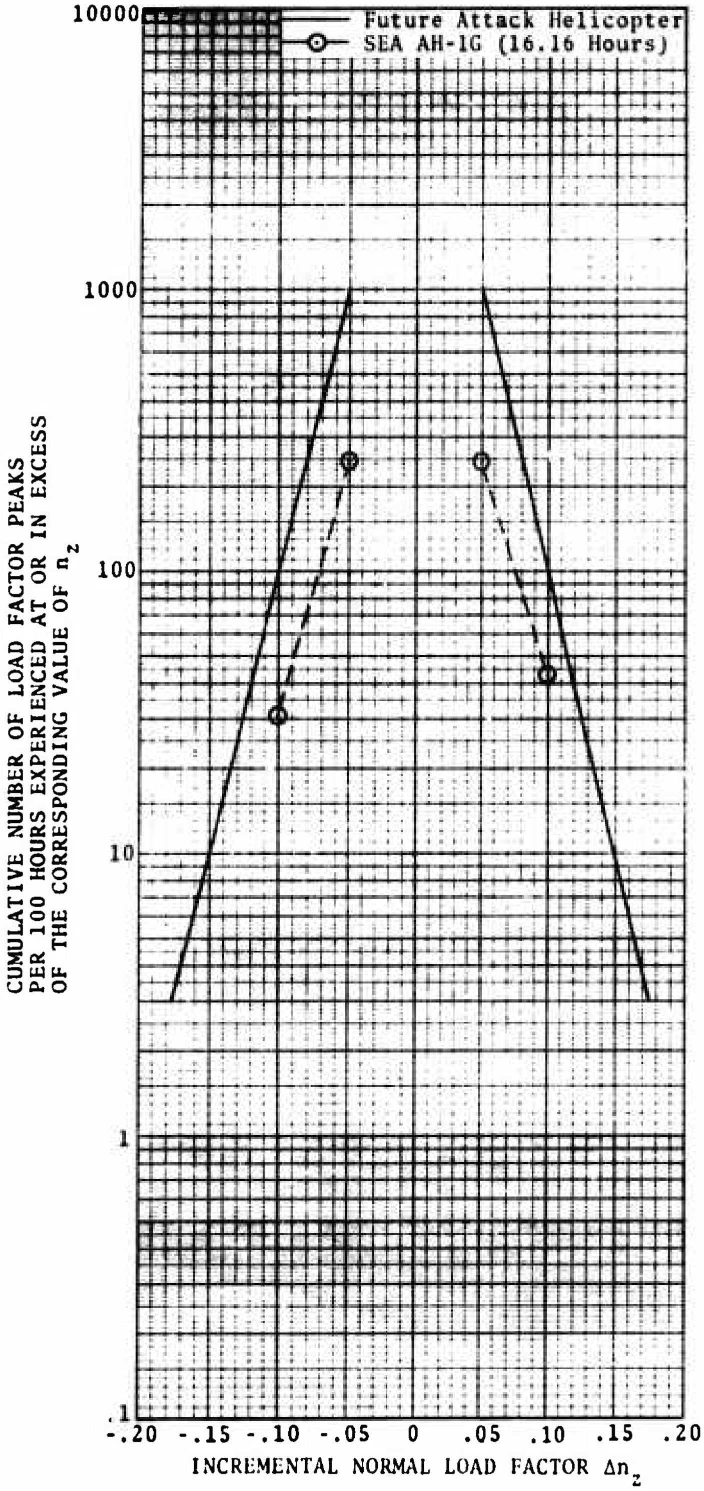


Figure 31. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Attack Helicopter.

2.5.3 Crane Helicopters

The future crane class, the heavy lift helicopter (HLH), will be designed to economically satisfy the logistic needs of the mobile forces. Its basic mission includes the transport of several types of payload, including engineer and artillery equipment, single-point hoist loads, containerized fuel and ammunition resupply, troop combinations, and command post vans and forward surgical operating rooms; the recovery of equipment; and the evacuation of medical units. A typical mission will fly 100 to 300 km at airspeeds between 80 and 100 knots and take 40 minutes to 2 hours.

The mission profile for the HLH will not differ from the operational mission profile for the SEA CH-54A. Figures 32 through 35 and Tables 51 and 52 represent the HLH mission profile.

TABLE 51. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE CRANE HELICOPTERS

Mission Segment / Flight Condition	Frequency*	
Ground Operations		10
Rotor Start	(27)	
Steady State, minimum	.49	
Steady State, average	1.17	
Steady State, maximum	5.14	
Transient	1.38	
Rotor Stop	(27)	
Ground Taxi	1.82	
Hover		20
Steady State, minimum	2.60	
Steady State, average	4.60	
Steady State, maximum	6.18	
Takeoff	.28	
Collective Pull-Up	.30	
Collective Pushover	.30	
Touchdown	(80)	
Longitudinal Reversal	.02	
Lateral Reversal	.02	
Initiation of Ascent	.55	
Cargo Pickup	1.00	
Cargo Drop	.75	
Left Turn	1.50	
Right Turn	1.50	
Cyclic Pullup	.20	
Cyclic Pushover	.20	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentages of total mission time.

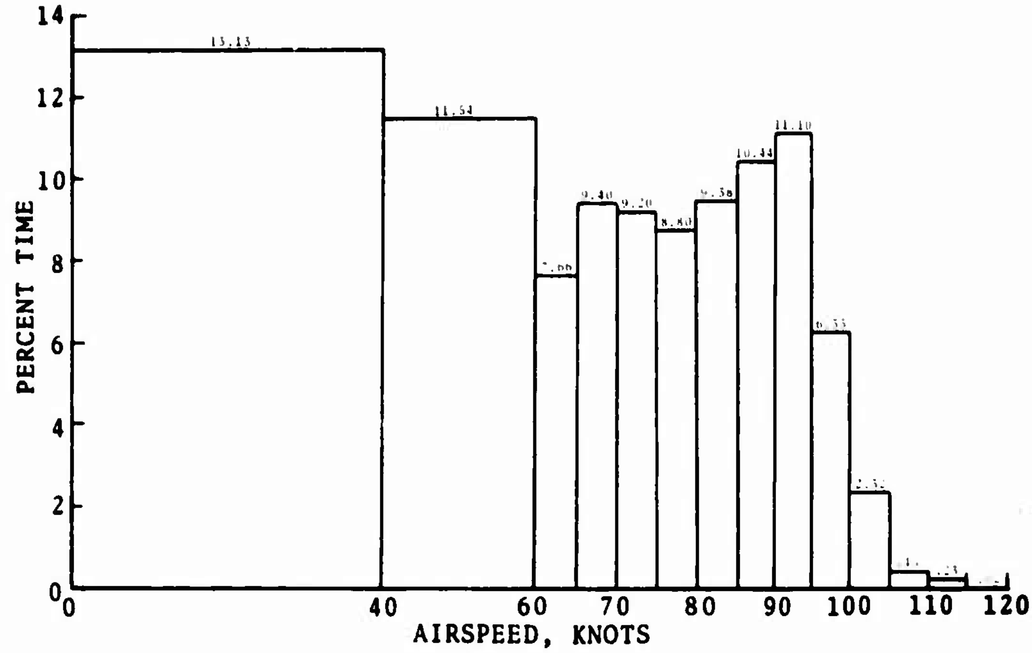
TABLE 51. (Continued)

Ascent		15
Steady State, minimum	1.00	
Steady State, average	3.50	
Steady State, maximum	5.00	
Takeoff	.79	
Collective Pull-Up	.34	
Collective Pushover	1.18	
Cyclic Pull-Up	.20	
Cyclic Pushover	.20	
Initiation of Ascent	.79	
Mission Segment Change without maneuver	(273)	
Left Turn	1.00	
Right Turn	1.00	
Level Flight		28
Steady State, minimum	2.00	
Steady State, average	5.00	
Steady State, maximum	15.75	
Collective Pull-Up	.37	
Collective Pushover	.88	
Mission Segment Change without maneuver	(193)	
Left Turn	2.00	
Right Turn	2.00	
Descent		12
Steady State, minimum	1.00	
Steady State, average	1.50	
Steady State, maximum	2.50	
Collective Pull-Up	1.14	
Collective Pushover	.80	
Cyclic Pull-Up	.06	
Cyclic Pushover	.06	
Flare	.81	
Touchdown	(33)	
Mission Segment Change without maneuver	(80)	
Left Turn	2.00	
Right Turn	2.00	
Cargo Drop	.13	
Full Power Climb		1

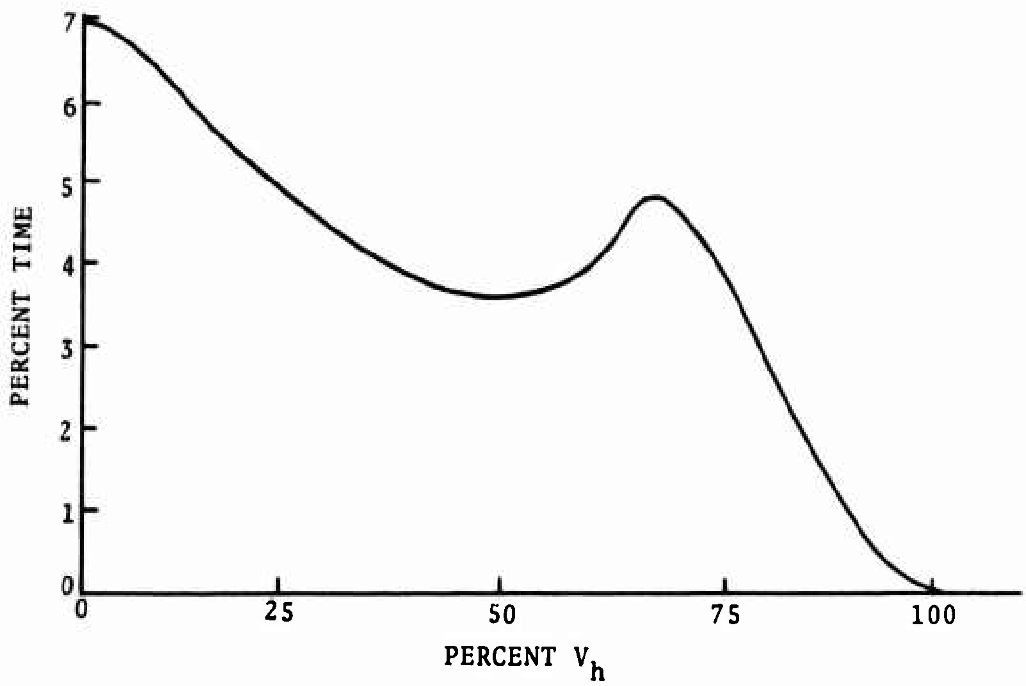
TABLE 51. (Concluded)		
Partial Power Descent		13
Steady State, minimum	.77	
Steady State, average	1.97	
Steady State, maximum	5.34	
Collective Pull-Up	.73	
Collective Pushover	1.18	
Cyclic Pull-Up	.04	
Flare	.97	
Touchdown	(13)	
Right Turn	1.00	
Left Turn	1.00	
I.G.E. Maneuver		1

TABLE 52. PERCENTAGE OF CRANE MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA CH-54A (%)	Future A/C (%)
Hover	0.006	0.014
Ascent	0.006	0.012
Level Flight	0.000	0.008
Descent	0.015	0.029
Partial Power Descent	0.011	0.017



a. Operational Mission Profile



b. Future Mission Profile

Figure 32. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Crane Helicopters.

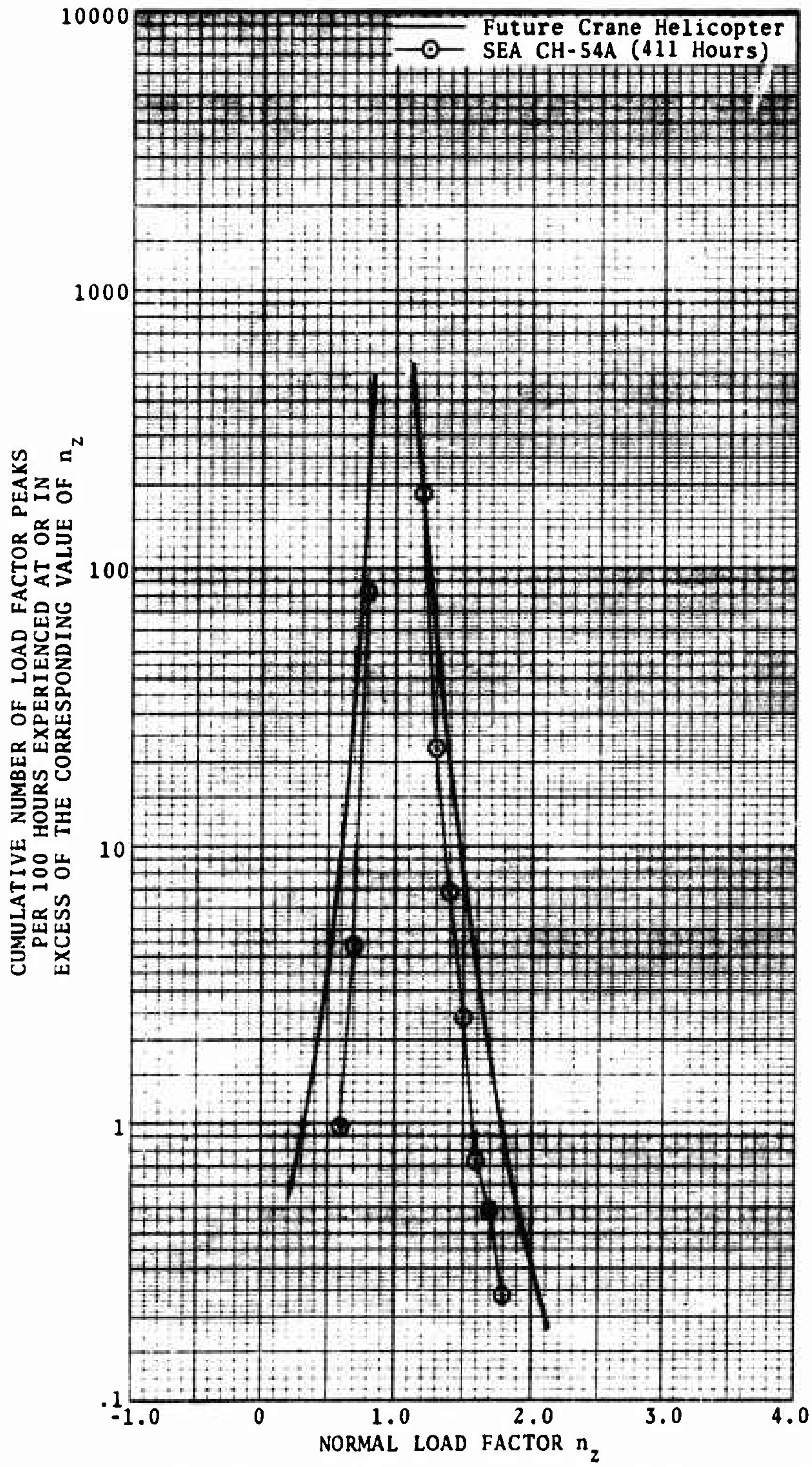


Figure 33. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Crane Helicopter.

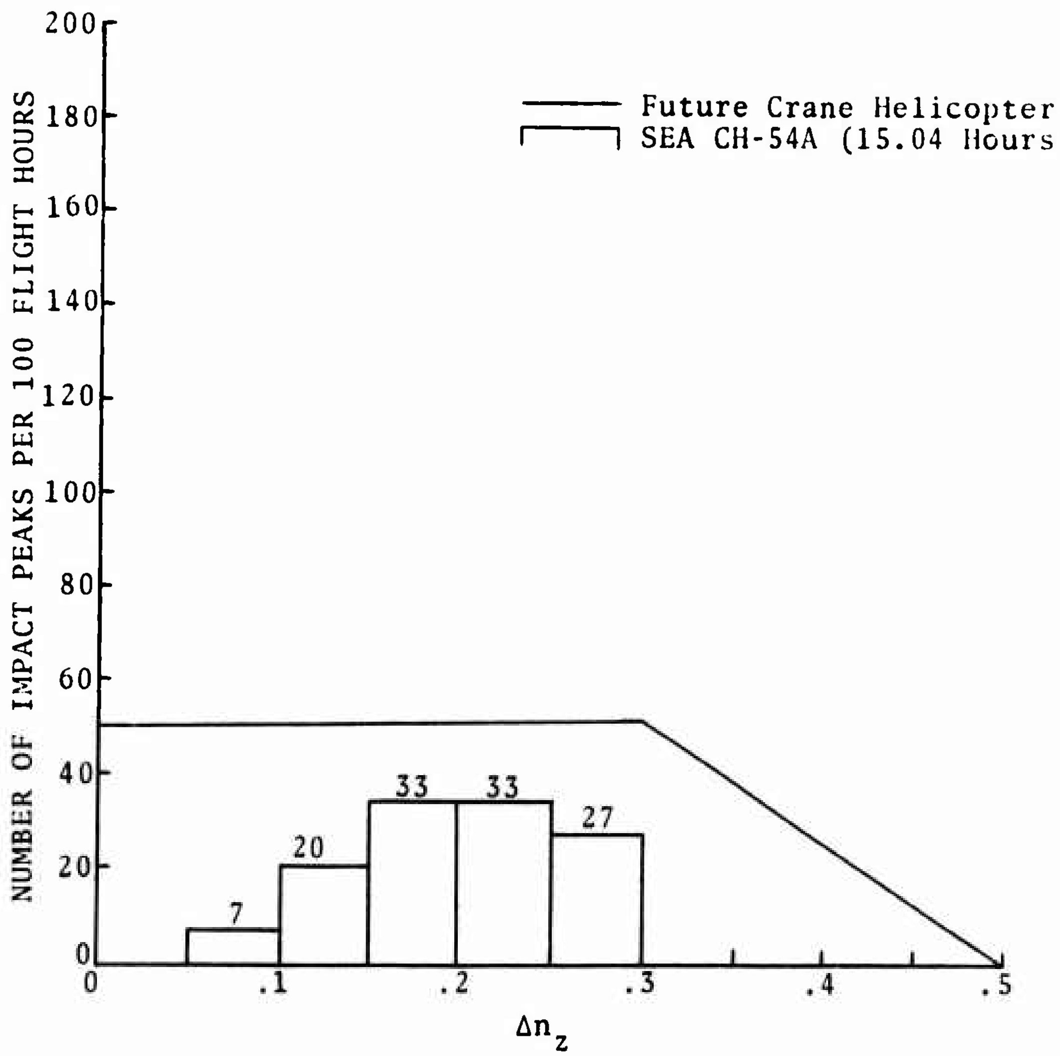


Figure 34. Landing Impact Peak Distribution of the Operational and Future Mission Profiles for the Crane Helicopter.

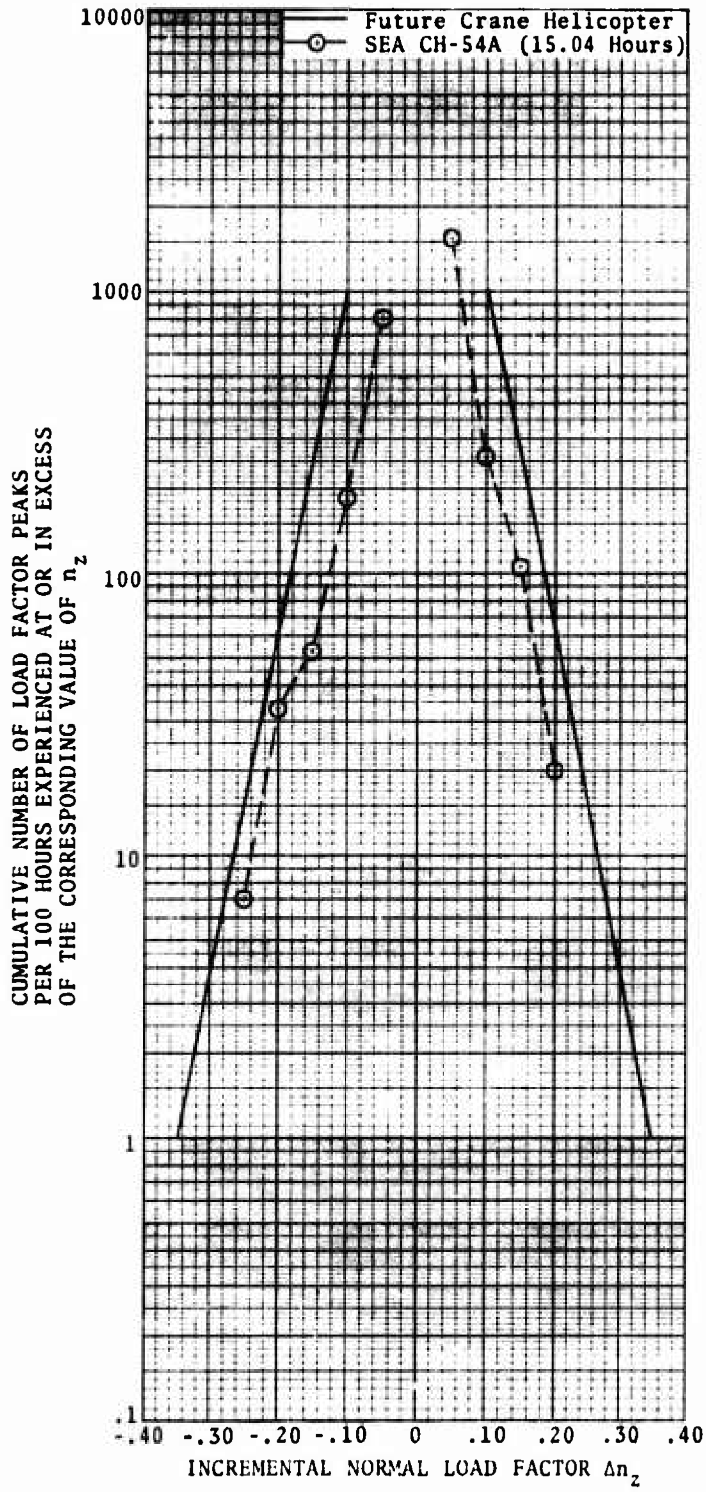


Figure 35. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Crane Helicopter.

2.5.4 Observation Helicopters

2.5.4.1 General

Future visual observation, reconnaissance, and command missions will likely be performed by the light observation helicopter (LOH). These missions will be flown along and behind the forward edge of the battle area (FEBA). The LOH will reconnoiter to select air routes, holding areas, and attack positions; then during operations with the attack helicopter platoon leader aboard, it will designate targets and direct the movement of attack helicopters.

Such missions will require fast-twisting NOE flying, steep maximum n_z turns to avoid enemy radar, pop-up maneuvers at airspeeds ranging from hover to 100 knots, and hovering out of ground effect.

The SEA OH-6A performance was similar to that anticipated for the LOH.

The following paragraphs discuss the LOH mission profile as represented in Figures 36 through 39 and in Tables 53 and 54.

2.5.4.2 Mission Segments

2.5.4.2.1 Ground Operations

The LOH will likely not spend as much time on combat ground areas as the SEA OH-6A.

2.5.4.2.2 Hover

Because of the threat from enemy air defense, the LOH will generally hover out of view and consequently have more collective pushovers and pull-ups, rudder turns, and longitudinal and lateral cyclic reversals while maneuvering among the trees than the SEA OH-6A.

2.5.4.2.3 Ascent and Descent

Because of the NOE flying techniques to be employed, the LOH will spend nearly the same amount of time in the ascent and descent segments as the SEA OH-6A but will have more cyclic and collective pushovers and pull-ups than the SEA OH-6A.

TABLE 53. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE OBSERVATION HELICOPTERS

Mission Segment Flight Condition	Frequency*	
Ground Operations		10
Rotor Start	(33)	
Steady State, minimum	.60	
Steady State, average	2.58	
Steady State, maximum	5.41	
Transient	1.05	
Rotor Stop	(33)	
Ground Taxi	.36	
Hover		20
Steady State, minimum	1.00	
Steady State, average	2.00	
Steady State, maximum	6.29	
Takeoff	1.50	
Collective Pull-Up	2.33	
Collective Pushover	1.98	
Cyclic Pull-Up	1.43	
Cyclic Pushover	1.46	
Touchdown	(128)	
Longitudinal Reversal	.10	
Lateral Reversal	.10	
Rudder Turn	2.10	
Initiation of Ascent	.71	
Ascent		9
Steady State, minimum	.32	
Steady State, average	.61	
Steady State, maximum	2.78	
Takeoff	0.11	
Collective Pull-Up	1.50	
Collective Pushover	1.42	
Cyclic Pull-Up	.91	
Cyclic Pushover	.97	
Initiation of Ascent	.15	
Mission Segment Change without maneuver	(100)	
Left Turn	.01	
Right Turn	.22	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentages of total mission time.

TABLE 53. (Continued)

Level Flight		10
Steady State, minimum	.75	
Steady State, average	1.50	
Steady State, maximum	3.00	
Collective Pull-Up	.87	
Collective Pushover	.86	
Cyclic Pull-Up	.60	
Cyclic Pushover	.60	
Mission Segment Change without maneuver	(17)	
Takeoff	.02	
Left Turn	.90	
Right Turn	.90	
Descent		9
Steady State, minimum	.18	
Steady State, average	.55	
Steady State, maximum	2.25	
Collective Pull-Up	1.59	
Collective Pushover	1.76	
Cyclic Pull-Up	.75	
Cyclic Pushover	.75	
Flare	.34	
Touchdown	(78)	
Mission Segment Change without maneuver	(43)	
Left Turn	.41	
Right Turn	.42	
I.G.E. Maneuver		34
Steady State, minimum	.59	
Steady State, average	1.02	
Steady State, maximum	2.70	
Takeoff	.06	
Collective Pull-Up	8.50	
Collective Pushover	6.80	
Cyclic Pull-Up	.68	
Cyclic Pushover	.60	
Longitudinal Reversal	1.92	
Lateral Reversal	2.00	
Initiation of Ascent	.03	
Mission Segment Change without maneuver	(23)	
Left Turn	3.79	
Right Turn	5.17	
Flare	.14	
Touchdown	(15)	

TABLE 53. (Concluded)

Takeoff Power Climb		1
Initiation of Ascent	.87	
Collective Pull-Up	.10	
Collective Pushover	.03	
Full Power Climb		5
Steady State, minimum	.29	
Steady State, maximum	1.38	
Collective Pull-Up	.78	
Collective Pushover	.78	
Cyclic Pull-Up	.55	
Cyclic Pushover	.52	
Longitudinal Reversal	.03	
Lateral Reversal	.03	
Initiation of Ascent	.44	
Mission Segment Change without maneuver	(32)	
Left Turn	.05	
Right Turn	.15	
Partial Power Descent		2
Steady State	.40	
Collective Pull-Up	.38	
Collective Pushover	.42	
Flare	.45	
Mission Segment Change without maneuver	(16)	
Left Turn	.13	
Right Turn	.20	
Longitudinal Reversal	.02	

TABLE 54. PERCENTAGE OF OBSERVATION MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA OH-6A (%)	Future A/C (%)
Ascent	0.97	1.98
Level Flight	0.10	0.15
Descent	3.14	6.08
I.G.E. Maneuver	7.65	22.61
Full Power Climb	0.66	1.42
Partial Power Descent	3.28	4.76

2.5.4.2.4 Level Flight

Although the LOH will spend much less time in level flight, again because of the NOE flying techniques, it will have more collective and cyclic pull-ups and pushovers in this segment.

2.5.4.2.5 In Ground Effect

The LOH will have more NOE flights at low speeds and pop-up and evasive maneuvers near the ground than the SEA OH-6A. Moreover, the LOH will have more cyclic and collective pull-ups and pushovers in this segment.

2.5.4.2.6 Full Power Climb (Intermediate Power Climb)

Because of the NOE flights involving pop-up maneuvers in the combat area, the LOH will likely have more than twice the percentage of time in this segment than the SEA OH-6A.

2.5.4.2.7 Takeoff Power Climb

Because of its greater power, the LOH will likely use an intermediate power climb, rather than a takeoff power climb, except in hot environments.

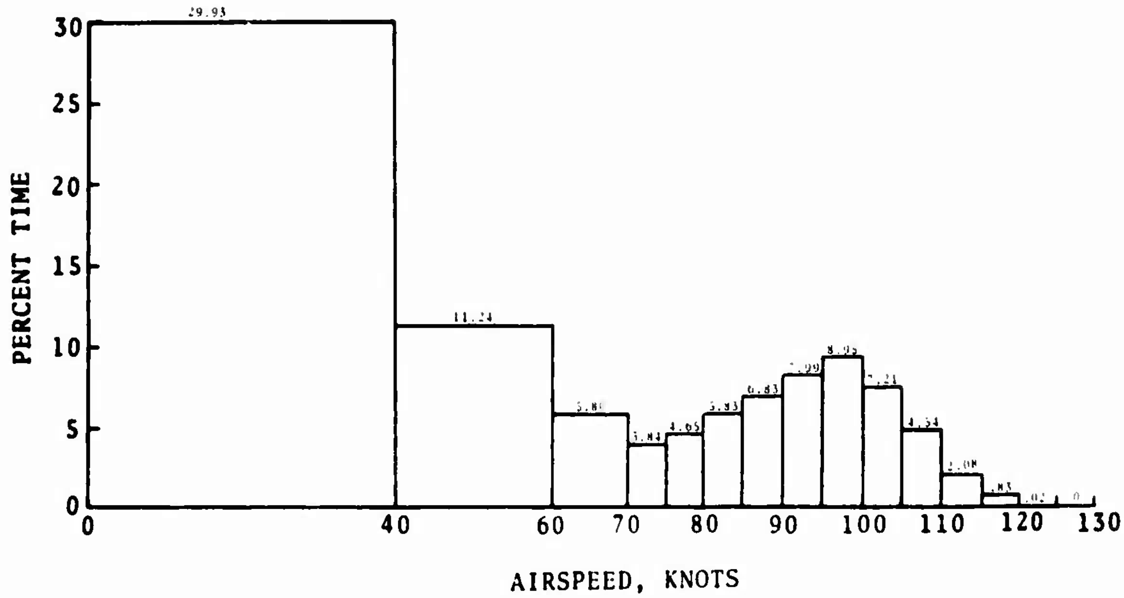
2.5.4.3 Airspeeds

Because of the NOE flying techniques to be employed both at low speeds (0 to 15 knots) and intermediate airspeeds (80 to 100 knots), the percentages of time in airspeed ranges for the LOH will change considerably from those for the SEA OH-6A. Figure 36 compares the percentages for the SEA OH-6A with those expected for the LOH.

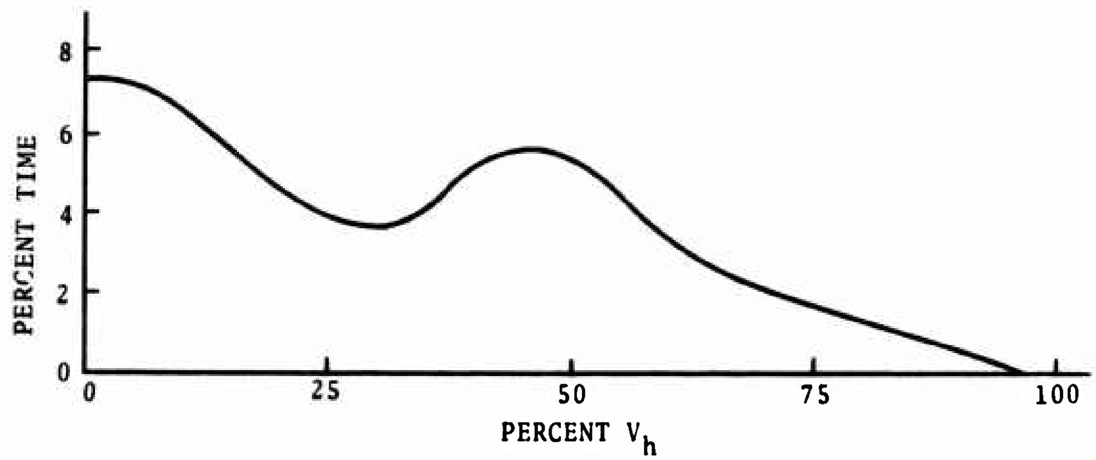
2.5.4.4 Normal Load Factors

2.5.4.4.1 Maneuver

The maneuver n_z's of the LOH will vary considerably from those of the SEA OH-6A because of the future requirements for steep turns during NOE flights and pop-up maneuvers. Table 54 compares the percentage of time that the SEA OH-6A had maneuvers outside the n_z threshold with that estimated for the LOH, and Figure 37 compares the cumulative maneuver n_z distributions for the two aircraft.



a. Operational Mission Profile



b. Future Mission Profile

Figure 36. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Observation Helicopters.

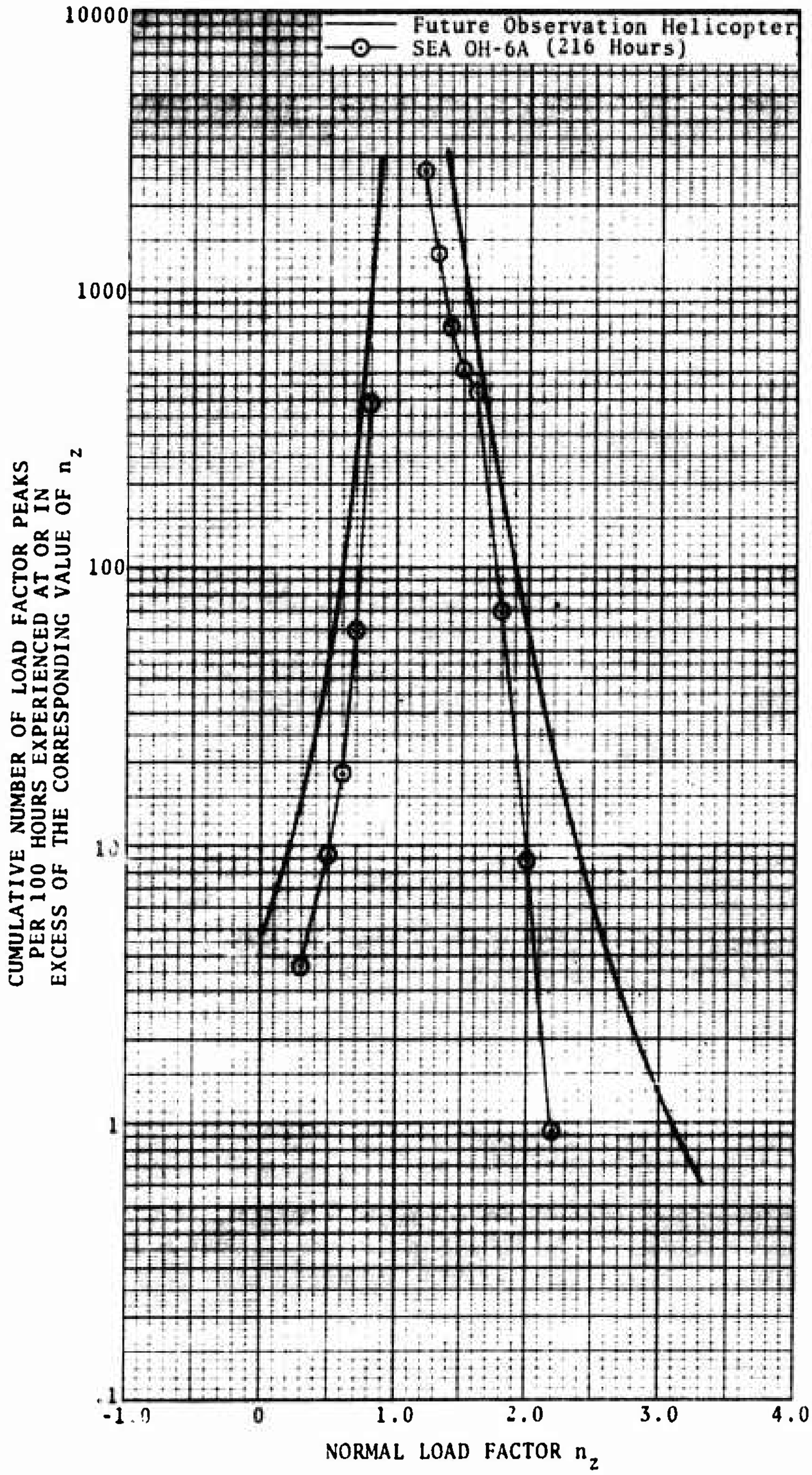


Figure 37. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Observation Helicopter.

2.5.4.4.2 Landing Impact and Taxi

Under normal operating conditions the landing impact and taxi Δn_z's of the LOH will generally be the same as those experienced in SEA. During intense warfare, however, the likelihood of inadvertent hard landings increases. Since such landings may occur when the aircraft has a large gross weight, the Δn_z distribution in Figure 38 has higher values for the LOH than for the SEA OH-6A. In Figure 39, the cumulative taxi Δn_z distribution for the LOH closely agrees with that for the SEA OH-6A.

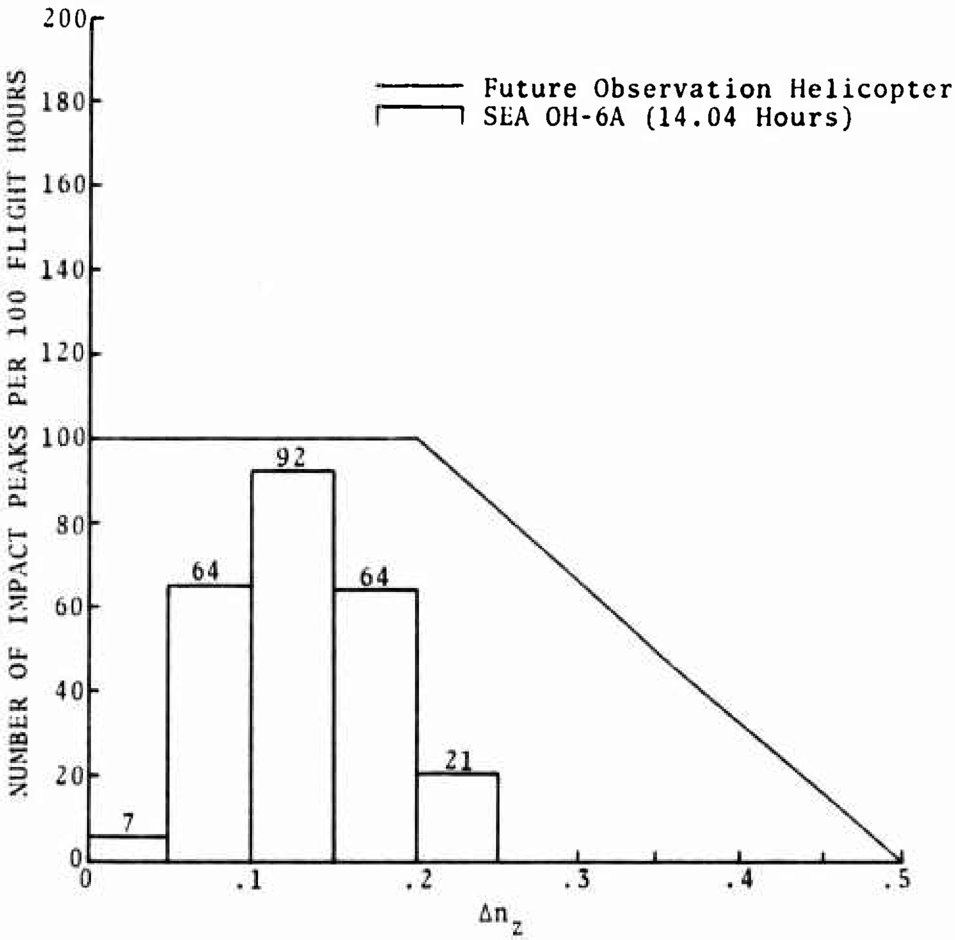


Figure 38. Landing Impact Peak Distribution of the Operational and Future Mission Profiles for the Observation Helicopters.

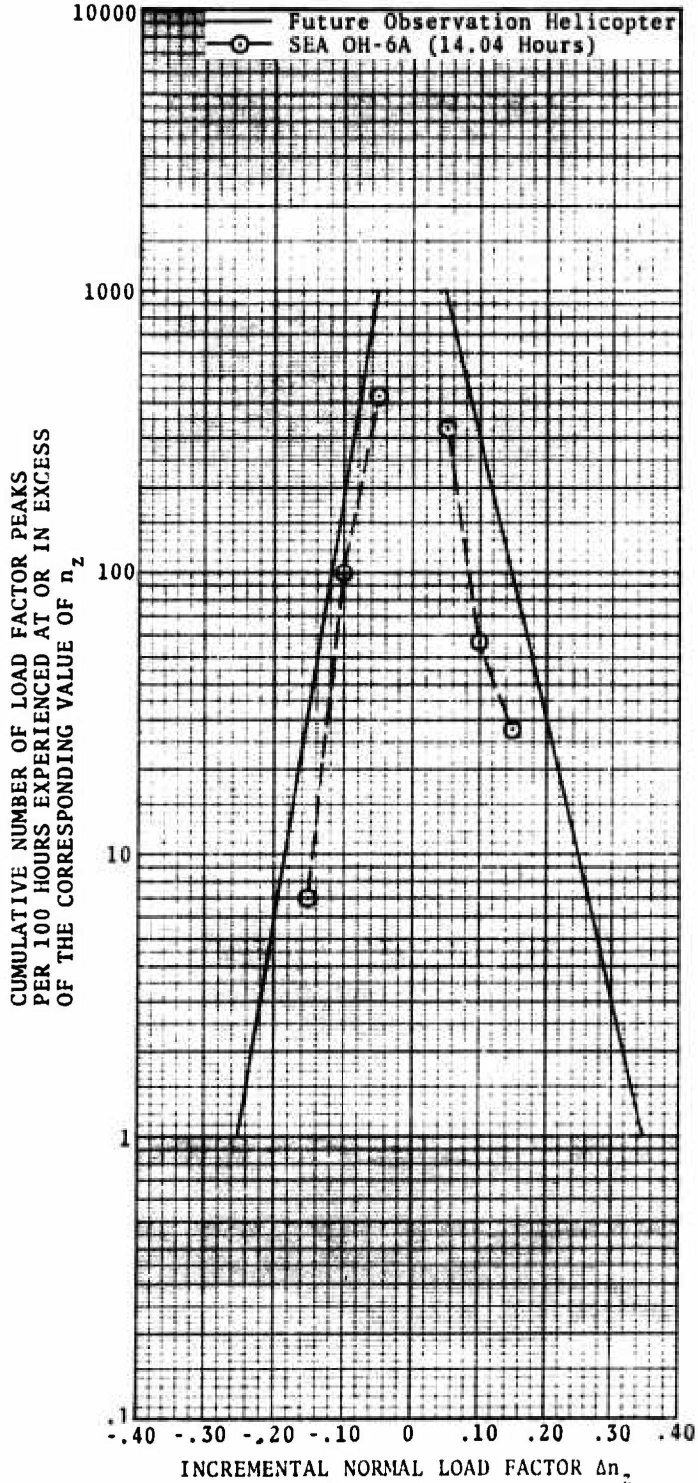


Figure 39. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Observation Helicopter.

2.5.5 Assault Helicopters

2.5.5.1 General

The SEA UH-1H, when performing assault-type missions, initially flew at high altitudes when small arms ground fires were a threat, but later flew at low cruise altitudes when SAM's and NOE flying techniques were introduced. Future assault missions will be flown by the Army UTTAS which will also operate as a utility helicopter, as discussed later. With its greater maneuverability, the UTTAS, as an assault helicopter, will provide more battlefield coverage, perform precise tactical maneuvers, and fly NOE and evasive maneuvers with maximum n_z turns to avoid enemy radar detection and weapons. As defined in the following paragraphs, the intensity of warfare operation will determine the flight tactics and techniques to be employed and consequently the helicopter operational requirements.

Low-intensity operations will be similar to those of the SEA UH-1H when performing assault missions because of SAM's. The future assault helicopter will initially cruise at low altitudes (<100 ft above ground level (AGL)). Within about 15 km of the landing zone, the UTTAS will fly NOE at treetop levels (<50 ft AGL). Cruise airspeeds will average 50 knots, and NOE flights will have 3- to 5-second maximum-acceleration turns.

Midintensity operations in the Middle East will generally be over flat terrain where desert vegetation and obstacles will be relatively sparse. The UTTAS will cruise at airspeeds averaging 100 knots and at low altitudes (100 ft AGL) which will be reduced to about 50 ft AGL upon reaching the landing zone to avoid enemy radar detection. In addition to NOE flying, high n_z turns may be required over the landing zone.

Midintensity operations in Europe will generally be NOE flights at altitudes below 50 ft AGL to escape enemy radar detection. Airspeeds will average 50 knots because of the density of electrical power and telephone wires. Maximum n_z turns of 3 to 5 seconds duration will be executed along cruise routes and over the landing zones.

The following paragraphs discuss the future assault mission profile as represented in Figures 40 through 43 and in Tables 55 and 56.

TABLE 55. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE ASSAULT HELICOPTERS

Mission Segment Flight Condition	Frequency*	
Ground Operations		6
Rotor Start	(34)	
Steady State, minimum	.58	
Steady State, average	1.50	
Steady State, maximum	2.50	
Transient	1.42	
Rotor Stop	(34)	
Hover		12
Steady State, minimum	1.35	
Steady State, average	2.50	
Steady State, maximum	4.50	
Takeoff	1.20	
Collective Pull-Up	.23	
Collective Pushover	.17	
Cyclic Pull-Up	.07	
Cyclic Pushover	.07	
Touchdown	(383)	
Longitudinal Reversal	.20	
Lateral Reversal	.20	
Initiation of Ascent	.63	
Mission Segment Change without maneuvers	(107)	
Rudder Turn	.88	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentage of total mission time.

TABLE 55. (Continued)

Ascent		12
Steady State, minimum	1.00	
Steady State, average	2.00	
Steady State, maximum	3.21	
Takeoff	.19	
Collective Pull-Up	.70	
Collective Pushover	.70	
Cyclic Pull-Up	1.00	
Cyclic Pushover	1.00	
Longitudinal Reversal	.05	
Lateral Reversal	.05	
Initiation of Ascent	.10	
Mission Segment Change without maneuver	(228)	
Left Turn	1.00	
Right Turn	1.00	
Level Flight		20
Steady State, minimum	1.50	
Steady State, average	2.50	
Steady State, maximum	4.00	
Collective Pull-Up	2.00	
Collective Pushover	2.00	
Cyclic Pull-Up	2.00	
Cyclic Pushover	2.00	
Mission Segment Change without maneuver	(36)	
Left Turn	2.00	
Right Turn	2.00	
Descent		9
Steady State, minimum	.62	
Steady State, average	1.50	
Steady State, maximum	1.75	
Collective Pull-Up	.88	
Collective Pushover	.88	
Cyclic Pull-Up	.75	
Cyclic Pushover	.75	
Flare	.75	
Touchdown	(5)	
Mission Segment Change without maneuver	(5)	
Left Turn	1.00	
Right Turn	1.00	

TABLE 55. (Concluded)		
Full Power Climb		3
Steady State	.47	
Collective Pull-Up	.25	
Collective Pushover	.25	
Cyclic Pull-Up	.25	
Cyclic Pushover	.25	
Longitudinal Reversal	.01	
Lateral Reversal	.01	
Initiation of Ascent	.01	
Left Turn	.75	
Right Turn	.75	
Partial Power Descent		6
Steady State, minimum	.64	
Steady State, average	1.00	
Steady State, maximum	1.62	
Collective Pull-Up	.14	
Collective Pushover	.63	
Cyclic Pull-Up	.50	
Cyclic Pushover	.50	
Flare	.59	
Left Turn	.19	
Right Turn	.19	
Touchdown	(5)	
I.G.E. Maneuver		32
Steady State, minimum	2.50	
Steady State, average	3.50	
Steady State, maximum	1.60	
Collective Pull-Up	2.50	
Collective Pushover	2.50	
Cyclic Pull-Up	2.50	
Cyclic Pushover	2.50	
Left Turn	4.50	
Right Turn	4.50	
Longitudinal Reversal	.20	
Lateral Reversal	.30	
Initiation of Ascent	.50	

2.5.5.2 Mission Segments

2.5.5.2.1 Ground Operations

Whereas the SEA UH-1H spent a large percentage of time in ground operations, the UTTAS will spend much less time in this segment, especially in midintensity warfare operation.

2.5.5.2.2 Hover

Because of the considerable enemy ground fire threat near the landing zone, the assault aircraft will discharge troops and supplies from hover to minimize time in the area. Nevertheless, the time in the hover segment will be comparable to that for the SEA UH-1H.

2.5.5.2.3 Ascent and Descent

Because of the NOE flying techniques to be employed, the UTTAS will have less time in ascent and descent and increased cyclic and collective pull-ups and pushovers than the SEA UH-1H.

2.5.5.2.4 Level Flight

In comparison with the SEA UH-1H performance, the UTTAS will spend much less time in level flight because of its NOE flying, but the cyclic and collective pull-ups and pushovers in this segment will increase.

2.5.5.2.5 Full Power Climb (Intermediate Power Climb)

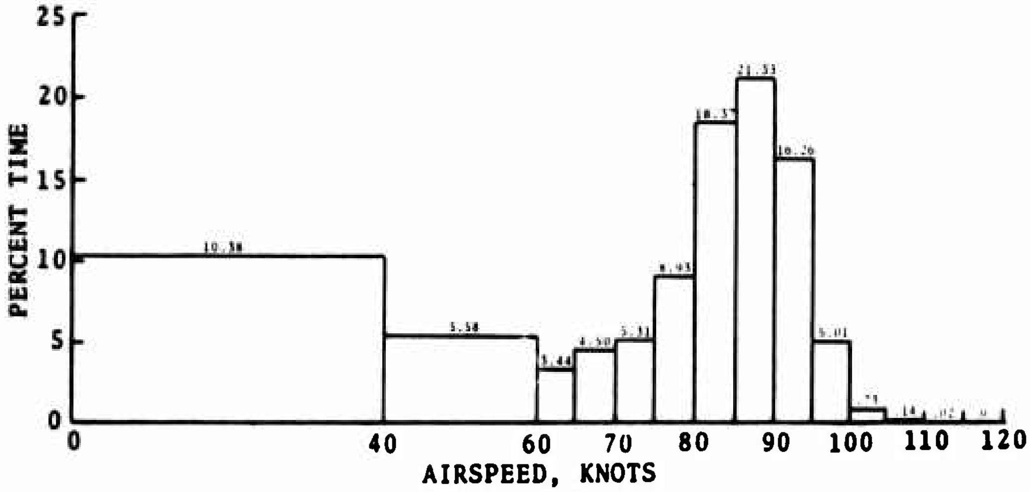
Because of its NOE flying, the UTTAS will likely spend more time in this segment than the SEA UH-1H.

2.5.5.2.6 Takeoff Power Climb

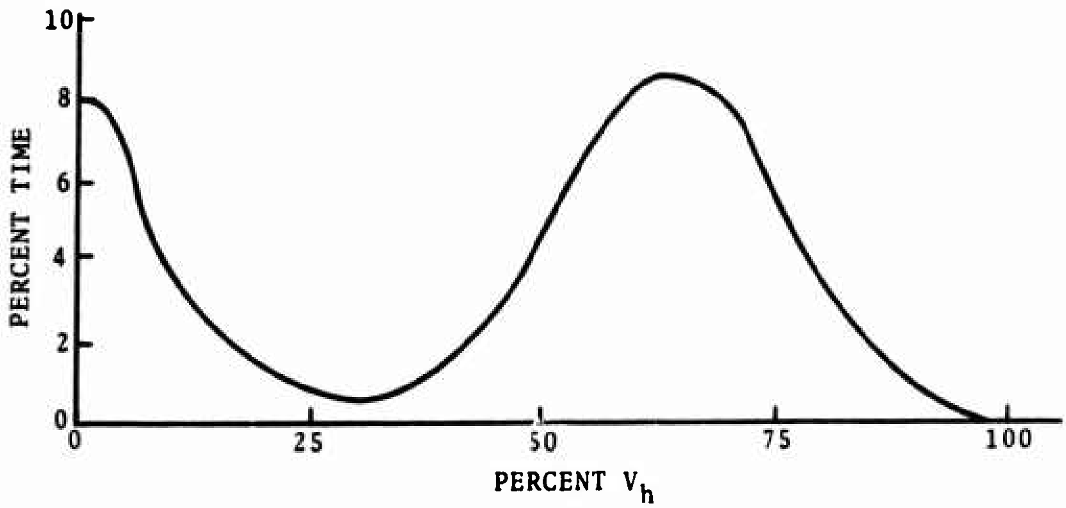
Since the higher power on the UTTAS will be used only in hot climates, the percentage of time in this segment will be small.

2.5.5.3 Airspeeds

Before the introduction of SAM's, the SEA UH-1H flew at airspeeds near design cruise limits. However, as shown in Figure 40, the assault helicopter will fly at greatly reduced airspeeds because of NOE flying, particularly below 50 ft AGL.



a. Operational Mission Profile



b. Future Mission Profile

Figure 40. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Assault Helicopters.

2.5.5.4 Normal Load Factors

2.5.5.4.1 Maneuver

Because of the NOE flying with maximum n_z turns common, the assault helicopter will have considerably more maneuver n_z's than the SEA UH-1H. Table 56 compares the percentage of time that the SEA UH-1H had maneuver n_z's outside the n_z threshold with that estimated for the assault helicopter, and Figure 41 compares the cumulative maneuver n_z distribution for the two aircraft.

TABLE 56. PERCENTAGE OF ASSAULT MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA UH-1H (%)	Future A/C (%)
Ascent	0.00	0.25
Level Flight	0.00	0.25
Descent	0.14	0.27
Full Power Climb	1.92	5.39
Partial Power Descent	4.05	5.58

2.5.5.4.2 Landing Impact and Taxi

Under the anticipated operating conditions, the landing impact and taxi Δn_z's of the assault helicopter will generally be the same in magnitude and frequency as those of the SEA UH-1H. Figure 42 for the landing impact Δn_z's and Figure 43 for the taxi Δn_z's compare the Δn_z distributions for the two aircraft.

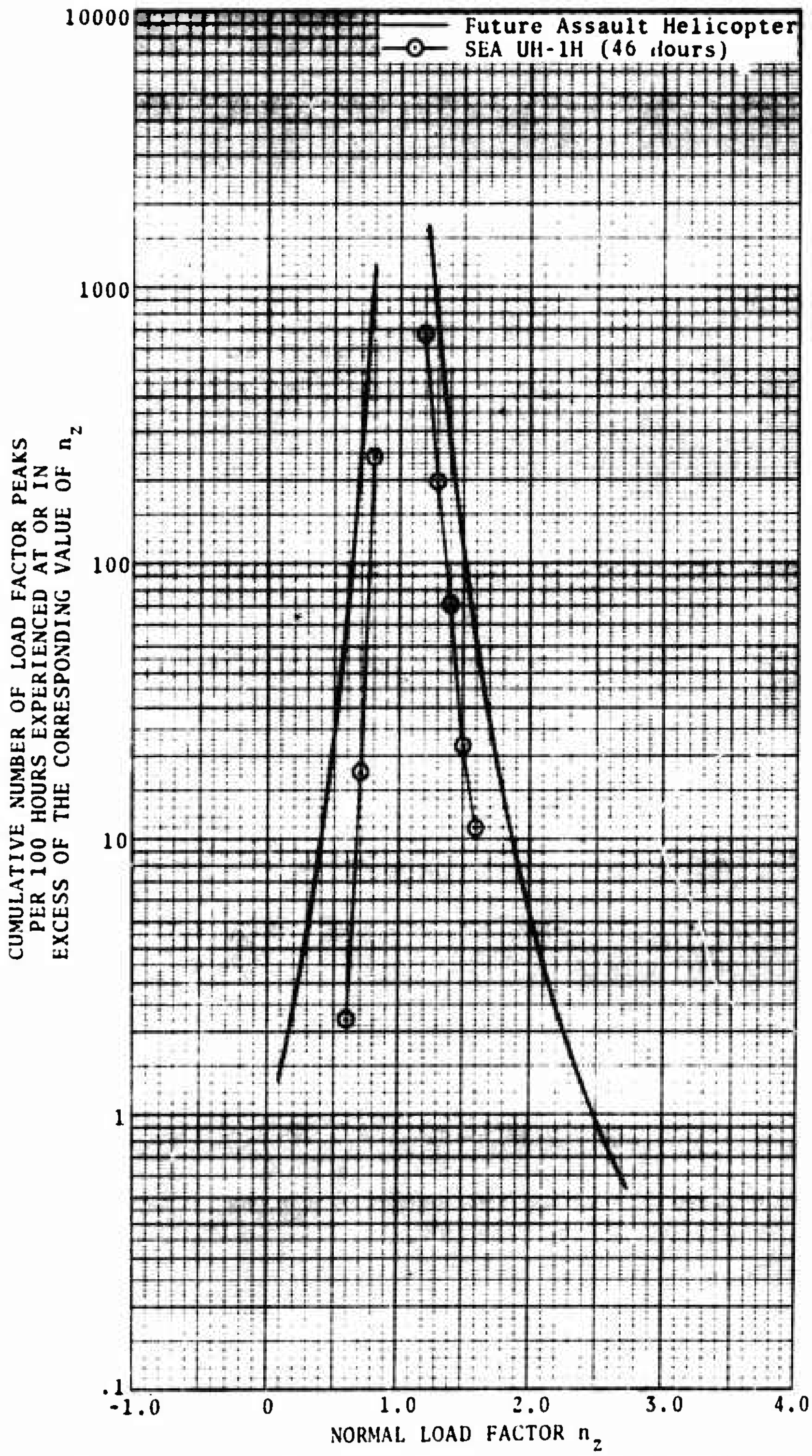


Figure 41. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Assault Helicopter.

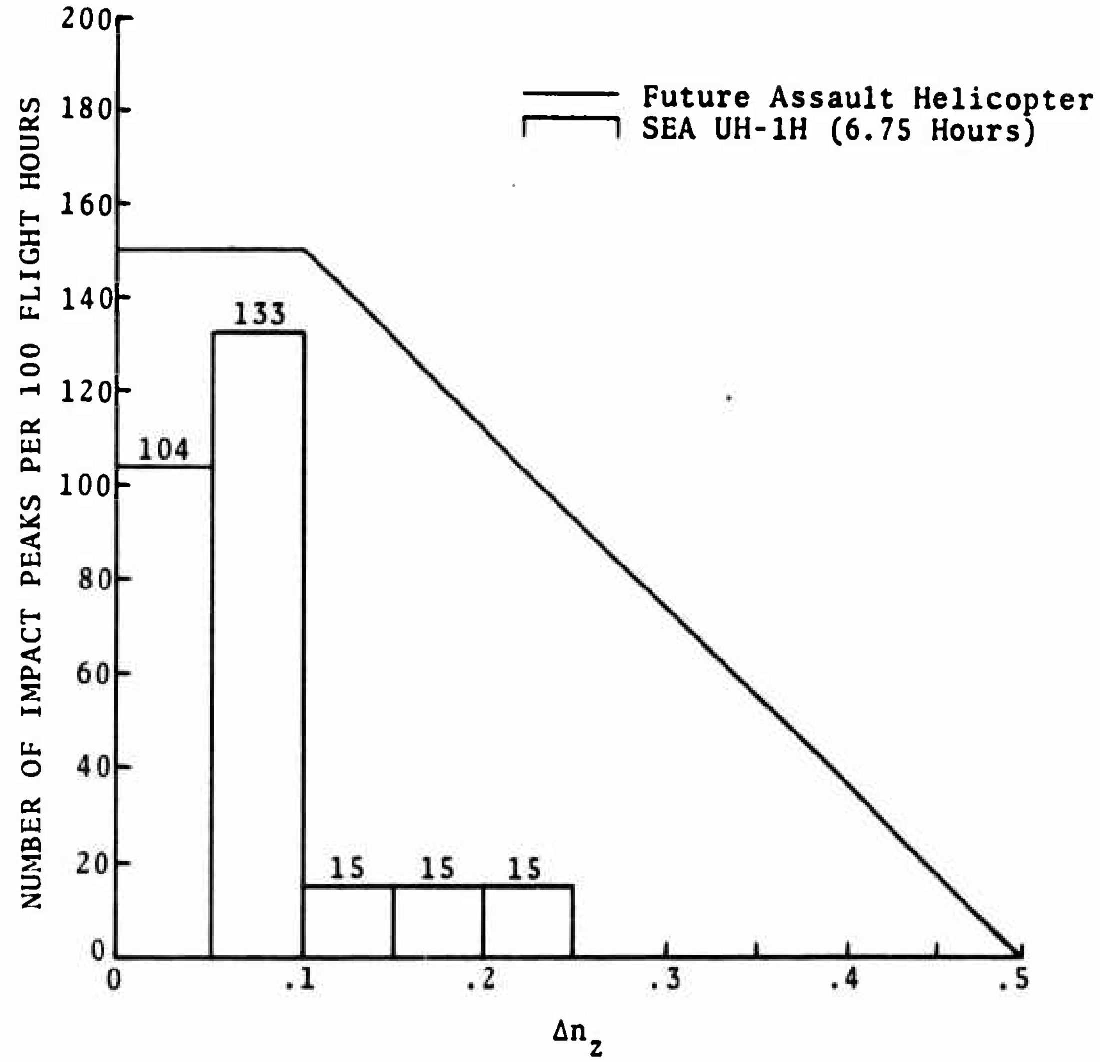


Figure 42. Landing Impact Peak Distribution of the Operational and Future Mission Profiles for the Assault Helicopter.

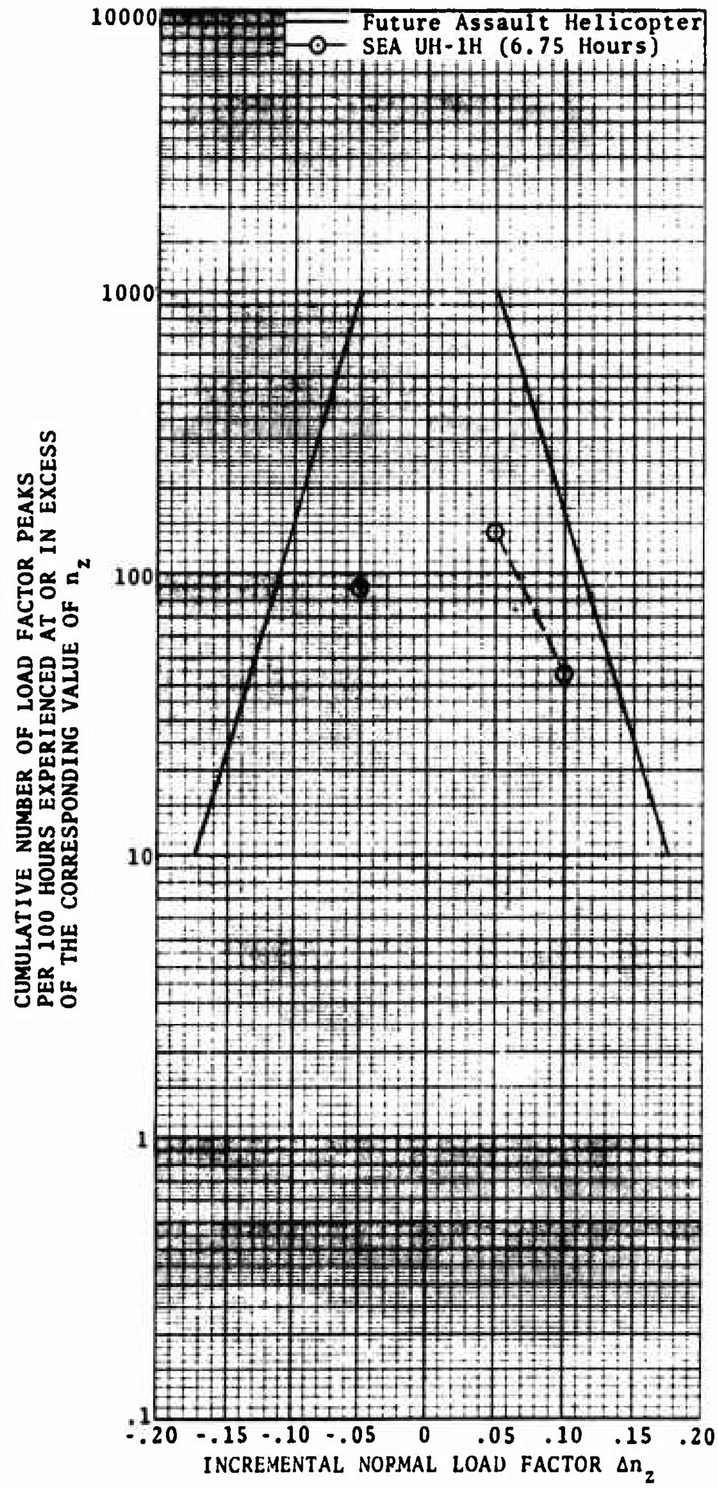


Figure 43. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Assault Helicopter.

2.5.6 Transport Helicopters

2.5.6.1 General

The SEA CH-47A data generally reflects the flying techniques during the early combat period when the enemy small arms ground threat was constant and the line of defense was not clearly defined. Flight altitudes ranged from 2000 to 5000 ft and airspeeds from 60 to 80 knots. After the SAM's were introduced, cruise altitudes decreased to below 100 ft AGL to avoid enemy radar detection, and airspeeds decreased correspondingly.

Whatever the theater and degree of warfare intensity, the future transport helicopter will have a mission profile similar to that for the SEA CH-47A. The future transport helicopter will initially cruise at altitudes of about 2000 ft AGL and at airspeeds of about 150 knots. Within 15 km of the forward landing zone, it will fly NOE at altitudes below 100 ft AGL and at airspeeds of about 50 knots.

The following paragraphs discuss the future transport mission profile as represented in Figures 44 through 47 and in Tables 57 and 58. This profile does not differ significantly from the operational mission profile for the SEA CH-47A.

2.5.6.2 Mission Segments

2.5.6.2.1 Ground Operations

Whereas the SEA CH-47A spent much time in ground operations, the future transport helicopter will spend considerably less time in this segment, especially in the mid-intensity warfare operation with its potential enemy weapons threat.

2.5.6.2.2 Hover

Since the future transport helicopter will generally carry the same amounts and types of cargo with comparable cargo loading and unloading as the SEA CH-47A, it will likely have a hover time approximately equal to that of the SEA CH-47A.

2.5.6.2.3 Ascent and Descent

Since the future transport helicopter will spend more time in cruise and some time in NOE flights, its time spent in ascents and descents should be nearly the same as that for the SEA CH-47A.

TABLE 57. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE TRANSPORT HELICOPTERS

Mission Segment Flight Condition	Frequency*	
Ground Operations		20
Rotor Start	(102)	
Steady State, minimum	.52	
Steady State, average	2.79	
Steady State, maximum	13.41	
Transient	2.97	
Rotor Stop	(102)	
Ground Taxi	.31	
Hover		15
Steady State, miminum	1.18	
Steady State, average	2.25	
Steady State, maximum	3.22	
Takeoff	.58	
Collective Pull-Up	.12	
Collective Pushover	.12	
Cyclic Pull-up	.10	
Cyclic Pushover	.10	
Touchdown	(225)	
Longitudinal Reversal	.07	
Lateral Reversal	.07	
Initiation of Ascent	.19	
Cargo Pickup	.50	
Cargo Drop	.50	
Left Turn	3.00	
Right Turn	3.00	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentages of total mission time.

TABLE 57. (Continued)

Ascent		15
Steady State, minimum	1.30	
Steady State, average	3.80	
Steady State, maximum	7.65	
Takeoff	.43	
Collective Pull-Up	.17	
Collective Pushover	49	
Cyclic Pull-Up	.30	
Cyclic Pushover	.16	
Longitudinal Reversal	.03	
Lateral Reversal	.03	
Initiation of Ascent	.60	
Mission Segment Change without maneuver	(409)	
Left Turn	.02	
Right Turn	.02	
Level Flight		15
Steady State, minimum	.55	
Steady State, average	3.85	
Steady State, maximum	10.24	
Collective Pull-Up	.03	
Collective Pushover	.15	
Cyclic Pull-Up	.03	
Cyclic Pushover	.13	
Mission Segment Change without maneuver	(195)	
Left Turn	.01	
Right Turn	.01	
Descent		11
Steady State, minimum	1.00	
Steady State, average	2.00	
Steady State, maximum	4.00	
Collective Pull-Up	.80	
Collective Pushover	.92	
Cyclic Pull-Up	.80	
Cyclic Pushover	.40	
Flare	.92	
Touchdown	(39)	
Mission Segment Change without maneuver	(520)	
Left Turn	.08	
Right Turn	.08	

TABLE 57. (Concluded)

Partial Power Descent		9
Steady State, minimum	.43	
Steady State, average	1.42	
Steady State, maximum	6.10	
Collective Pull-Up	.17	
Collective Pushover	.17	
Cyclic Pull-Up	.03	
Cyclic Pushover	.04	
Flare	.32	
Mission Segment Change without maneuver	(21)	
Left Turn	.16	
Right Turn	.16	
Touchdown	(20)	
Cargo Drop	.01	
I.G.E. Maneuver		15
Steady State	5.00	
Collective Pull-Up	1.00	
Collective Pushover	1.00	
Cyclic Pull-Up	1.00	
Cyclic Pushover	1.00	
Left Turn	3.00	
Right Turn	3.00	

TABLE 58. PERCENTAGE OF TRANSPORT MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA CH-47A (%)	Future A/C (%)
Ascent	0.10	0.19
Level Flight	0.01	0.02
Descent	0.76	1.35
Partial Power Descent	0.07	0.16

2.5.6.2.4 Level Flight

The future transport helicopter will likely spend the same percentage of time in level flight as the CH-47A because the increased level flight due to more cruising will be counterbalanced by the decreased level flight due to more NOE flying.

2.5.6.2.5 Full Power Climb (Intermediate Power Climb)

Although the future transport helicopter will use full or intermediate power for most takeoffs, it will have a small percentage of time in this climb segment.

2.5.6.2.6 Takeoff Power Climb

Since the higher power of the future transport helicopter will be used only in hot climates, the percentage of time in this segment will be small.

2.5.6.3 Airspeeds

Whereas the SEA CH-47A flew at airspeeds generally between 60 and 80 knots, the future transport helicopter will fly near 150 knots during cruise, generally at 2000 ft AGL, and below 50 knots during NOE flight. Figure 44 compares the airspeed distributions for the two aircraft.

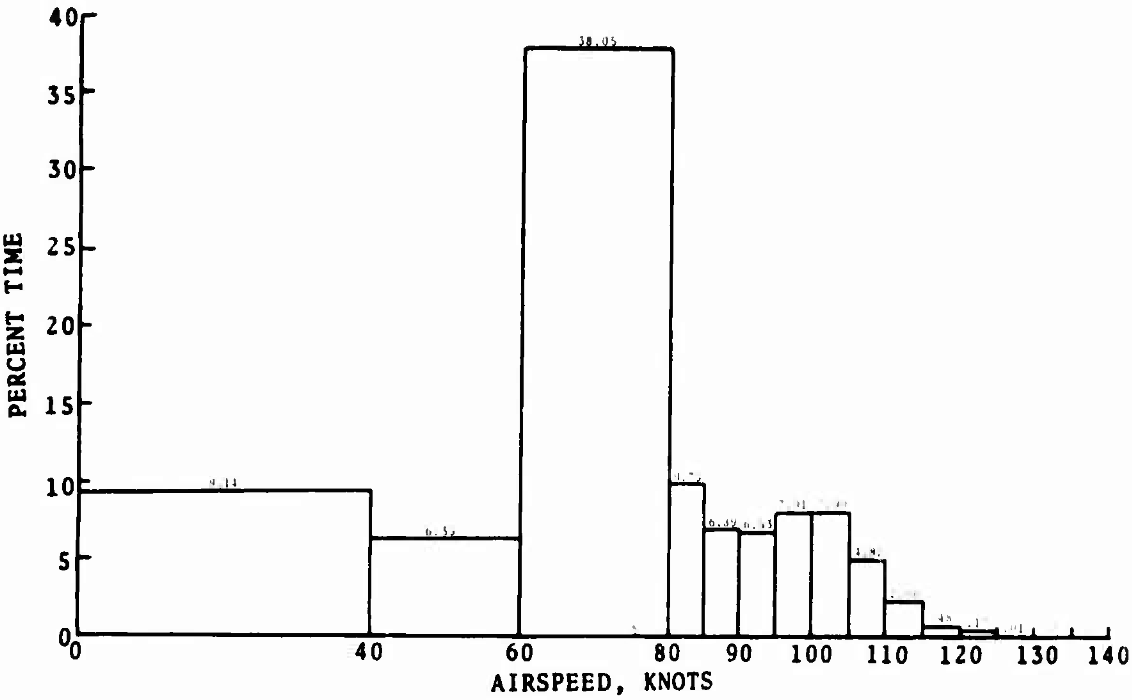
2.5.6.4 Normal Load Factors

2.5.6.4.1 Maneuver

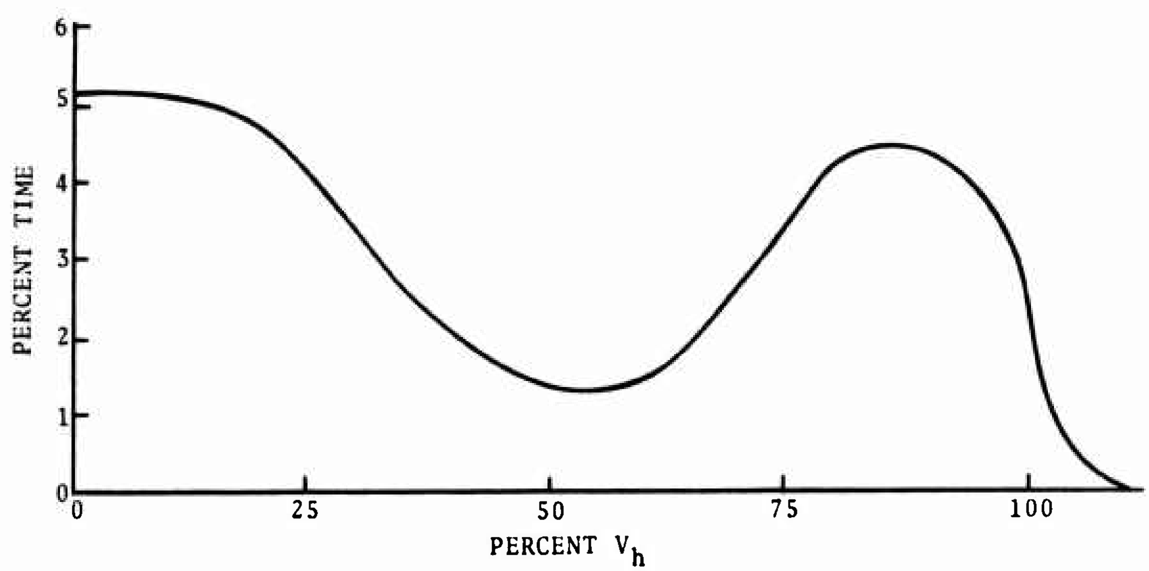
Even though NOE techniques will be used during future operations, large transport type aircraft should not experience more frequent or higher n_z's than the SEA CH-47A. Table 58 compares the percentage of time that the SEA CH-47A had maneuver n_z's outside the n_z threshold with that estimated for the future transport helicopter, and Figure 45 compares the cumulative maneuver n_z distributions for the two aircraft.

2.5.6.4.2 Landing Impact and Taxi

The landing impact and taxi Δn_z's of the future transport helicopter will generally be the same in magnitude and frequency as those of the SEA CH-47A. Figure 46 for the landing impact Δn_z's and Figure 47 for the taxi Δn_z's compare the Δn_z distributions for the two aircraft.



a. Operational Mission Profile



b. Future Mission Profile

Figure 44. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Transport Helicopters.

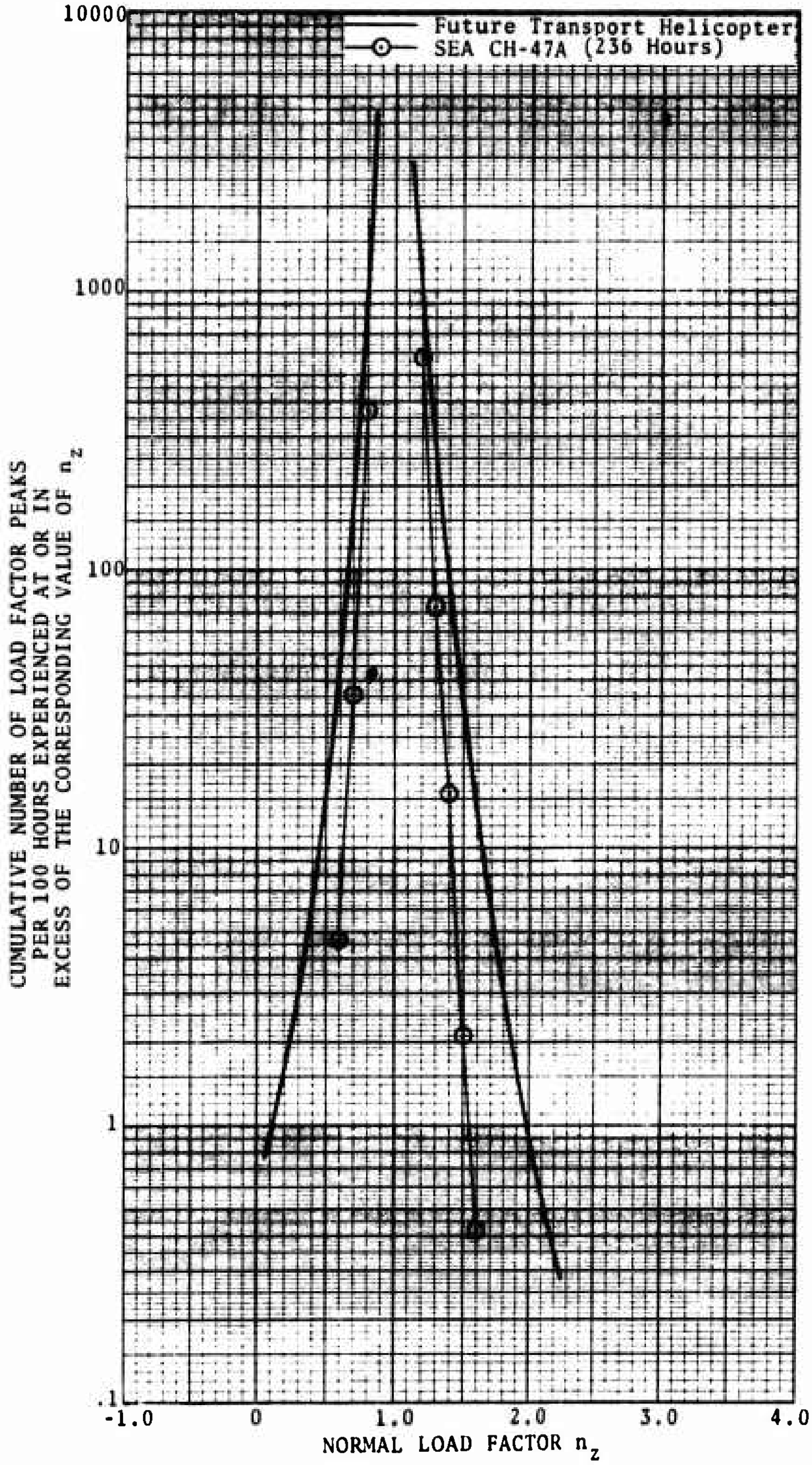


Figure 45. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Transport Helicopter.

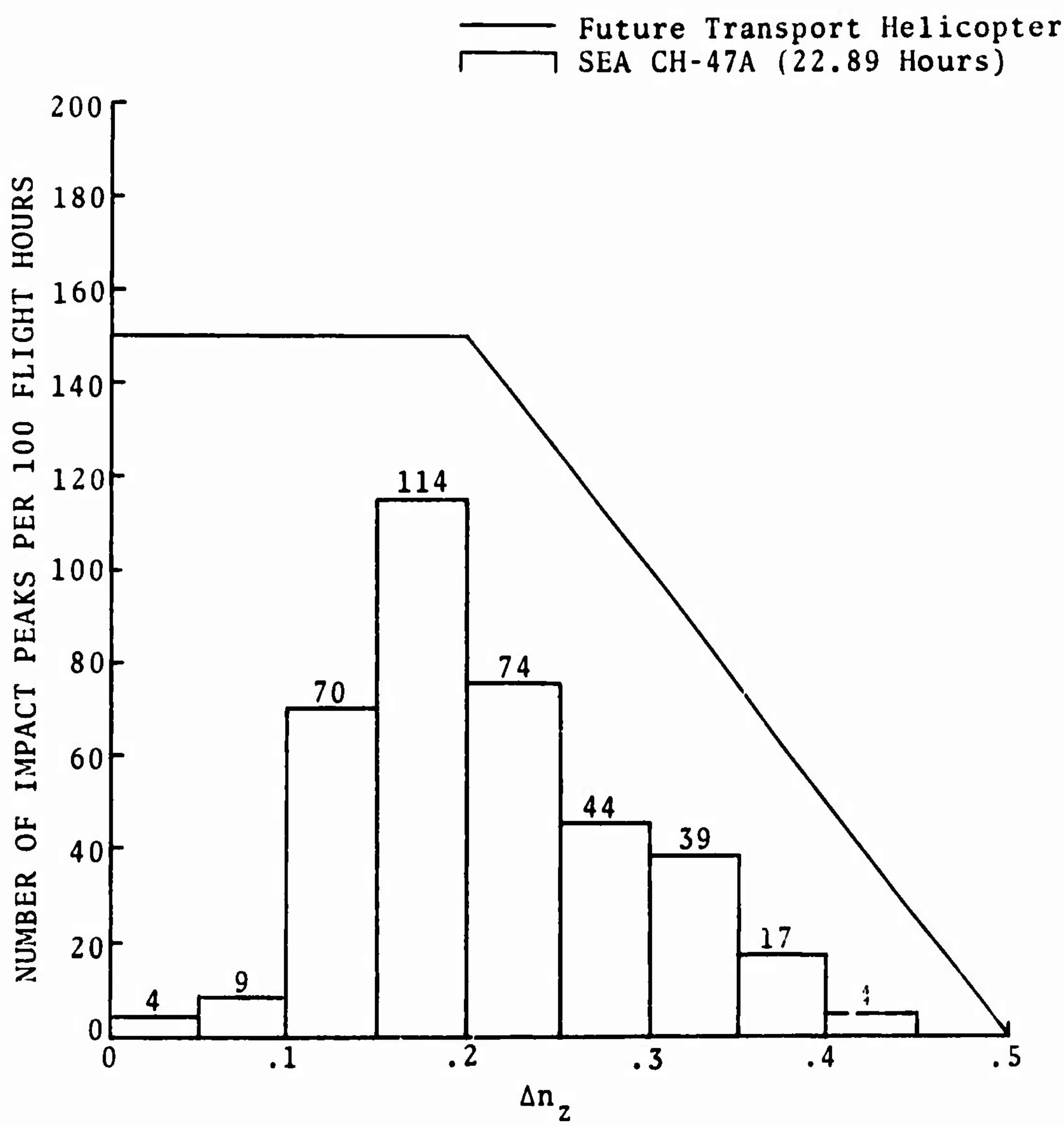


Figure 46. Landing Impact Peak Distribution of the Operational and Future Mission Profiles for the Transport Helicopter.

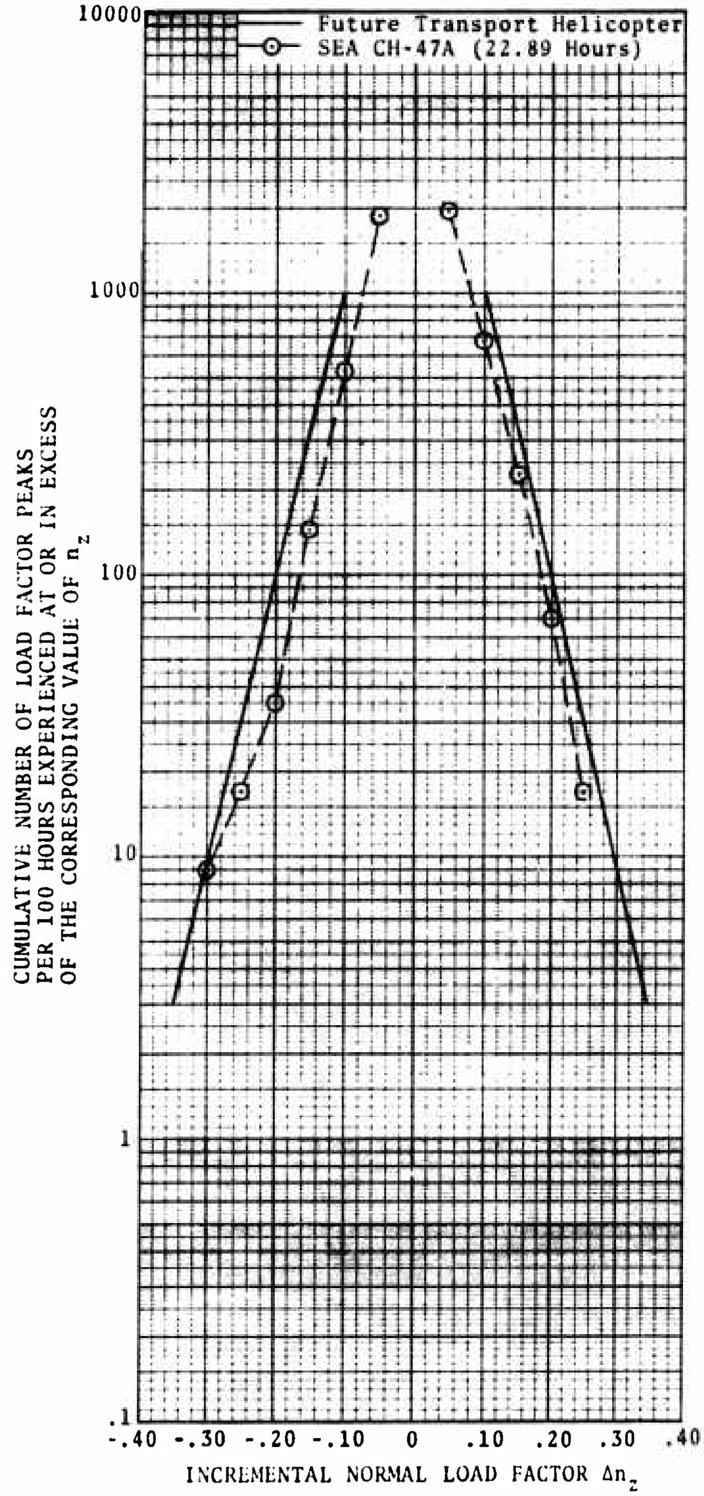


Figure 47. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Transport Helicopter.

2.5.7 Utility Helicopters

2.5.7.1 General

The utility missions performed by the SEA UH-1H were initially flown at high cruise altitudes because of the threat of small arms ground fire; after the introduction of SAM's and NOE flying, they were flown at low altitudes to avoid radar detection. Future utility missions will be flown by the Army UTTAS which will also operate as an assault helicopter. In its utility role, the UTTAS will provide battlefield support and consequently fly NOE and evasive maneuvers with maximum n_z turns to avoid enemy radar detection. As previously defined, the intensity of warfare operation will determine the flight tactics and techniques to be employed and consequently the operational requirements.

The following paragraphs discuss the future utility mission profile as represented in Figures 48 through 51 and in Tables 59 and 60.

2.5.7.2 Mission Segments

2.5.7.2.1 Ground Operations

Whereas the SEA UH-1H as a utility helicopter spent a large percentage of time in ground operations, the UTTAS also functioning as a utility helicopter will spend much less time in this segment because of the anticipated threat from enemy weapons.

2.5.7.2.2 Hover

Because of the considerable enemy ground fire threat near the landing zone, the UTTAS will hover over rather than land in the area to minimize the enemy opportunity for pinpointing the landing zone. Nevertheless, the time in the hover segment will be comparable to that for the SEA UH-1H.

2.5.7.2.3 Ascent and Descent

Because of the NOE flying techniques to be employed, the UTTAS will have less time in ascent and descent and increased cyclic and collective pull-ups and pushovers in these segments than the SEA UH-1H.

2.5.7.2.4 Level Flight

In comparison with the SEA UH-1H utility operation, the UTTAS will spend much less time in level flight because of its NOE flying, but the cyclic pull-ups and pushovers in this segment will increase.

5.7.2.5 Full Power Climb (Intermediate Power Climb)

Because of its NOE flying, the UTTAS will spend more time in this segment than the SEA UH-1H.

2.5.7.2.6 Takeoff Power Climb

Since the higher power on the UTTAS will be used only in hot climates, the percentage of time in this mission segment will be small.

2.5.7.3 Airspeeds

Before the introduction of SAM's, the SEA UH-1H flew at airspeeds near design cruise-altitude limits. However, as shown in Figure 48, the UTTAS will fly at airspeeds of about [illegible]0 knots when using NOE flying techniques.

2.5.7.4 Normal Load Factors

2.5.7.4.1 Maneuver

Because of the NOE flying with maximum n_z turns common, the UTTAS will have considerably more frequent and severe maneuver n_z's than the SEA UH-1H. Table 60 compares the percentage of time that the SEA UH-1H had maneuver n_z's outside the n_z threshold with that estimated for the UTTAS, and Figure 49 compares the cumulative maneuver n_z distributions for the two aircraft.

2.5.7.4.2 Landing Impact and Taxi

Under the anticipated operating conditions, the landing impact and taxi Δn_z's of the UTTAS will generally be the same in magnitude and frequency as those of the SEA UH-1H. Figure 50 for the landing impact Δn_z's and Figure 51 for the taxi Δn_z's compare the Δn_z distributions for the two aircraft.

TABLE 59. MISSION SEGMENT-FLIGHT CONDITION SPECTRA FOR FUTURE UTILITY HELICOPTERS

Mission Segment / Flight Condition	Frequency*	
Ground Operations		9
Rotor Start	(19)	
Steady State, minimum	.49	
Steady State, average	1.69	
Steady State, maximum	5.11	
Transient	1.67	
Rotor Stop	(19)	
Ground Taxi	.04	
Hover		16
Steady State, minimum	.60	
Steady State, average	1.65	
Steady State, maximum	3.42	
Takeoff	1.45	
Collective Pull-Up	1.30	
Collective Pushover	1.30	
Cyclic Pull-Up	1.30	
Cyclic Pushover	1.30	
Touchdown	(394)	
Longitudinal Reversal	.10	
Lateral Reversal	.10	
Initiation of Ascent	.48	
Mission Segment Change without maneuvers	(36)	
Left Turn	1.50	
Right Turn	1.50	

* Figures in parentheses represent the number of occurrences per 100 hours of mission time; other figures represent percentage of total mission time.

TABLE 59. (Continued)

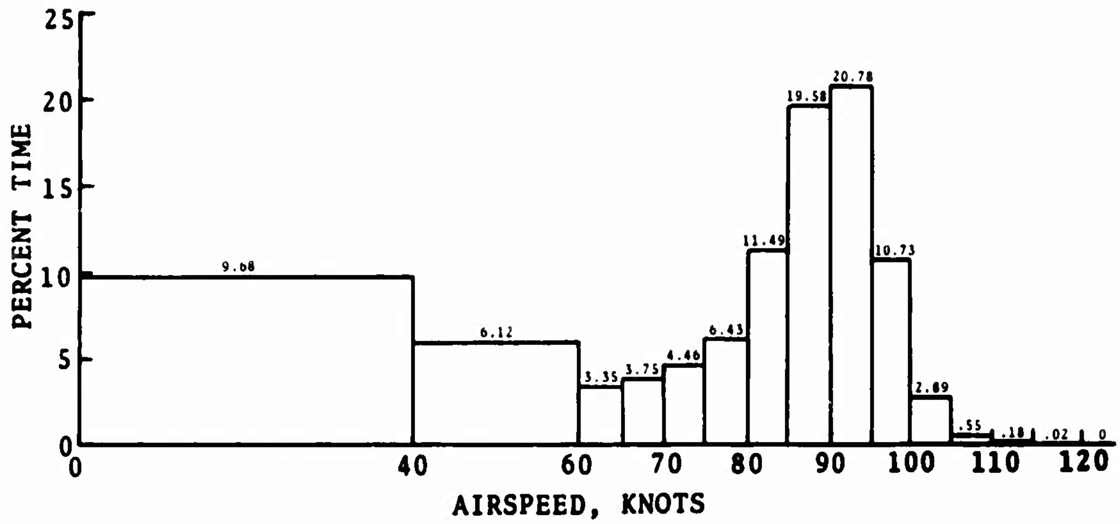
Ascent		20
Steady State, minimum	1.00	
Steady State, average	3.00	
Steady State, maximum	5.00	
Takeoff	.58	
Collective Pull-Up	1.50	
Collective Pushover	1.50	
Cyclic Pull-Up	1.50	
Cyclic Pushover	1.50	
Longitudinal Reversal	.10	
Lateral Reversal	.10	
Initiation of Ascent	.22	
Mission Segment Change without maneuver	(238)	
Left Turn	2.00	
Right Turn	2.00	
Level Flight		15
Steady State, minimum	1.20	
Steady State, average	3.50	
Steady State, maximum	5.00	
Collective Pull-Up	.70	
Collective Pushover	.70	
Cyclic Pull-Up	.70	
Cyclic Pushover	.70	
Mission Segment Change without maneuver	(17)	
Left Turn	1.25	
Right Turn	1.25	
Descent		14
Steady State, minimum	1.00	
Steady State, average	2.00	
Steady State, maximum	3.76	
Collective Pull-Up	.67	
Collective Pushover	.67	
Cyclic Pull-Up	.50	
Cyclic Pushover	.50	
Flare	.90	
Touchdown	(35)	
Mission Segment Change without maneuver	(51)	
Left Turn	2.00	
Right Turn	2.00	

TABLE 59. (Concluded)

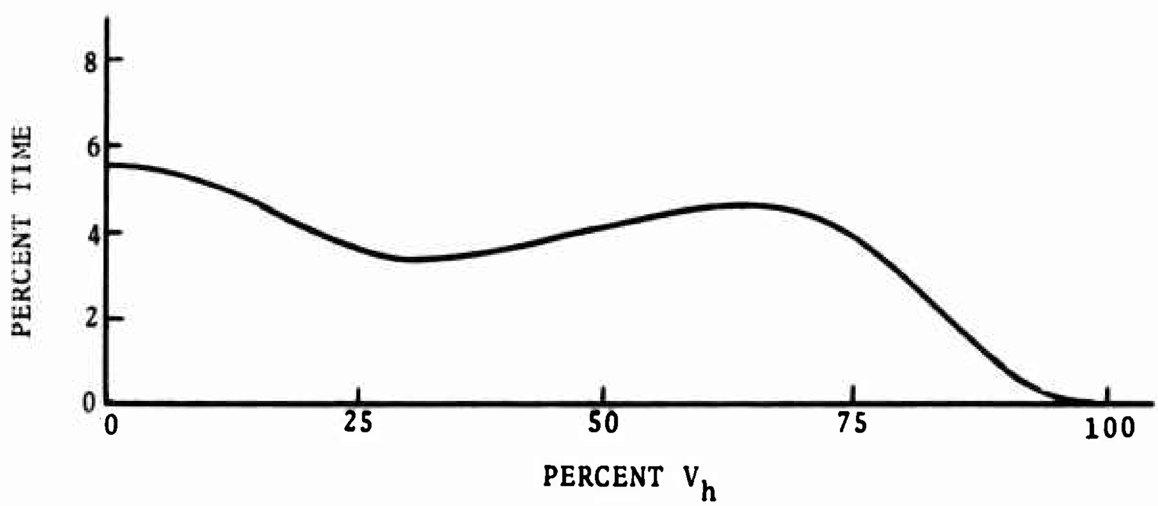
Partial Power Descent		6
Steady State, minimum	.29	
Steady State, average	.66	
Steady State, maximum	2.14	
Collective Pull-Up	.55	
Collective Pushover	.67	
Cyclic Pull-Up	.25	
Cyclic Pushover	.25	
Flare	1.08	
Left Turn	.03	
Right Turn	.08	
I.G.E. Maneuver		20
Steady State	10.00	
Collective Pull-Up	1.25	
Collective Pushover	1.25	
Cyclic Pull-Up	1.25	
Cyclic Pushover	1.25	
Left Turn	2.50	
Right Turn	2.50	

TABLE 60. PERCENTAGE OF UTILITY MISSION SEGMENT TIME FOR n_z's OUTSIDE THRESHOLD

Mission Segment	SEA UH-1H (%)	Future A/C (%)
Ascent	0.27	0.53
Level Flight	0.42	0.64
Descent	0.63	1.28
Partial Power Descent	1.93	2.76



a. Operational Mission Profile



b. Future Mission Profile

Figure 48. Airspeed Frequency Distribution of the Operational and Future Mission Profiles for the Utility Helicopters.

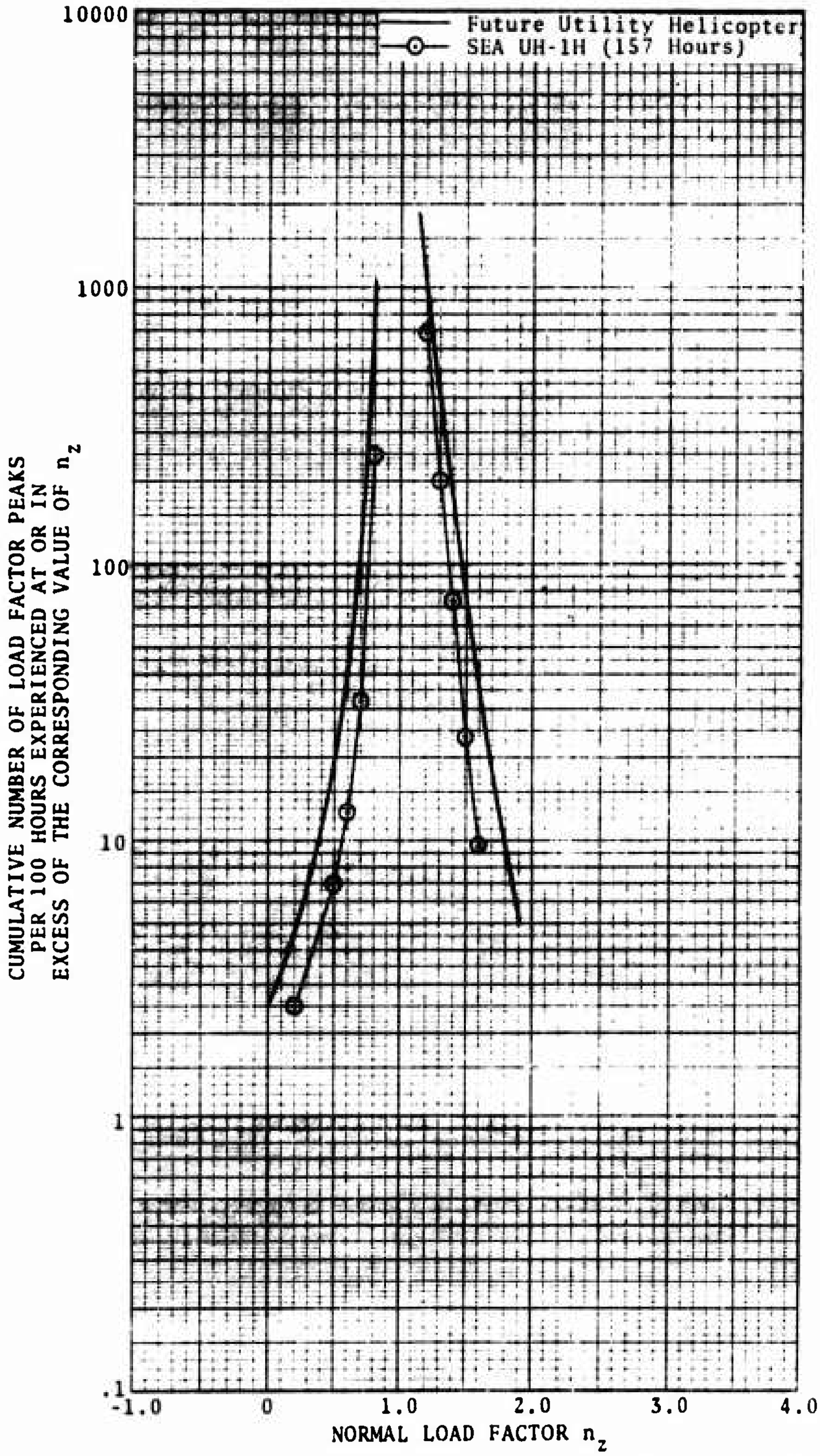


Figure 49. Cumulative Maneuver n_z Distribution for the Operational and Future Mission Profiles for the Utility Helicopter.

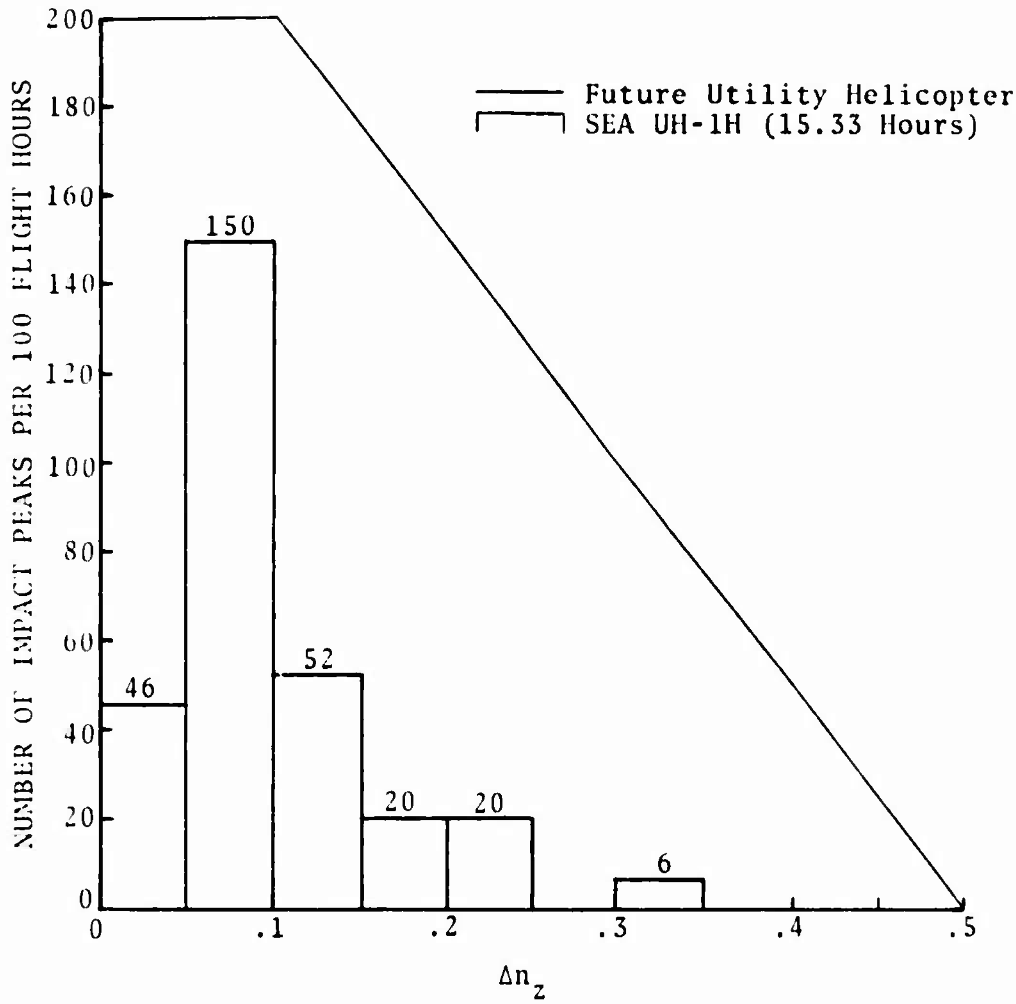


Figure 50. Landing Impact Peak Distribution of the Operational and Future Mission Profiles for the Utility Helicopter.

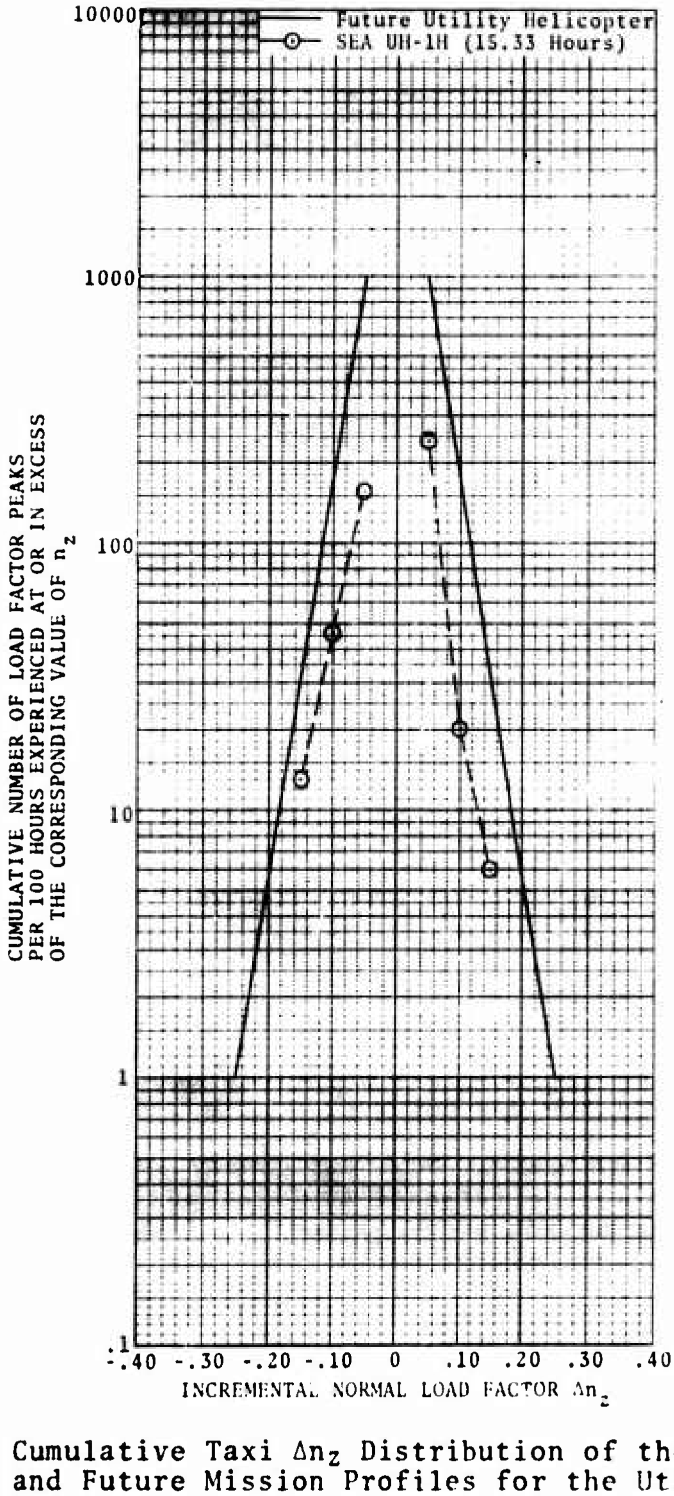


Figure 51. Cumulative Taxi Δn_z Distribution of the Operational and Future Mission Profiles for the Utility Helicopter.

3. SUMMARY AND CONCLUSIONS

During this study mission profiles for future helicopters were developed on the basis of SEA operational usage data, the mission requirements of both current and advanced helicopters, literature reviews, and consultations with pilots proficient in current and advanced tactics. Then these profiles were consolidated into a uniform and standardized format consistent with the requirements for fatigue analysis.

The development of the mission profile comparisons verified that the operational profiles may be converted to the formats of the manufacturer's design and Navy AR-56 mission profiles by making rational assumptions for some conditions. These comparisons revealed that the manufacturer's design and AR-56 mission profiles do not adequately represent operational usage.

Since ground time in the operational mission profiles ranged from 9.4 to 40 percent of the total mission time (the time basis for structural component replacement), while the manufacturer design and AR-56 mission profiles account for only some 1 percent of the ground time, helicopter components were likely replaced prematurely, that is, before the intended usage time.

Although the mission profiles developed for future helicopters in each of the six helicopter classes are reasonable and practical projections, they are tentative and subject to refinement with the subsequent application of the FCR technique to a larger and more comprehensive data sample. The small data sample limited the adequate development of some parameter distributions such as the maneuver n_z durations, the frequency of maneuver n_z's in n_z versus gross weight and c.g. position ranges, and the frequency of both landing impact and taxi Δn_z's in Δn_z versus gross weight ranges. Additionally, the small data sample did not represent all mission types normally flown by each helicopter class.

The design and operational applications of the future mission profiles to advanced helicopters should be considered in the light of the following constraints: high vibration, potential blade stall, and both high (as inducing structural failure in a static or dynamic overload condition) and cyclic (as inducing structural fatigue) loading conditions according to the structural aerodynamic and dynamic responses for a specific helicopter model with its particular airframe, rotor and control system, and operational requirements. By mission mixing and/or the development of new combat tactics, these constraints, as discussed in the following paragraphs, may be overcome.

As subsequently imposed on the main rotor hub, the dynamic response of the main rotor blades to control inputs is the main cause of high vibration which excites the entire fuselage and control system. The conditions which make high vibration possible are high airspeed, high rotor speed, high blade pitch angle due to either lateral or longitudinal collective control displacement, high roll rate, high maneuver vertical acceleration, and abrupt control motion.

Although not accounting for the potentially large effect of blade structural characteristics, estimates of blade stall may be based on the retreating blade angle of attack which depends on the advance ratio, blade loading coefficient, and drag-to-lift ratio. Blade stall induces high control loads, high blade stresses, and control power compromises. Any parameter which affects the flapwise response of the main rotor blades, such as high airspeed, gross weight, or load factor, will make blade stall possible.

Fatigue damage is induced in helicopter structural components by high cyclic loadings due primarily to the dynamic response of the main rotor blades and the consequent effects on the airframe and control system. The conditions which make high cyclic loadings possible are high airspeed, aircraft acceleration and deceleration caused by longitudinal and lateral cyclic pitch changes, severe maneuvers, numerous pedal turns during hover (which especially affect the tail rotor), and rotor start and stop cycles (which induce high stresses on components affected by centrifugal loading).

Additional conclusions drawn from this study are as follows:

(1) Since the general 10-hour data sample for each of the five helicopter models has percentages of time in the ascent, maneuver, descent, and steady-state mission segments that closely agree with the percentages for the total report data of the respective helicopter models, the individual data samples are representative of operational usage. However, the data samples were not large enough to permit developing adequate n_z frequency distributions associated with gross weight, c.g. position, parameter durations, etc.

(2) Although the four-mission-segment method is useful in identifying trends in operational usage data, the FCR technique produces more definitive data which better reflects operational usage. The FCR technique has the following additional data representations:

a. More numerous and descriptive mission segments and associated flight conditions.

b. Mission segments, flight conditions, and parameters expressed as durations and frequencies (number of occurrences per unit of time).

c. Mission profiles for each helicopter class.

d. In consequence of (a) through (c), more precise and realistic data to analyze structural fatigue and to establish uniform design criteria for each helicopter operational classification.

4. RECOMMENDATIONS

(1) The design, AR-56, and operational spectra should each include both GAG and rotor start-stop cycles, and the frequency, duration, and severity of the maneuvers.

(2) Separate mission profiles should be developed for each mission normally flown by each helicopter class and then combined to predict the operations of an entire fleet.

(3) To develop more representative operational mission profiles, the FCR technique should be applied to larger and more comprehensive samples of operational usage data.

(4) For aircraft whose gross weight and c.g. position variations are particularly important in reflecting operational usage, these parameters should be monitored so as to yield data that would be more definitive than those logged on the supplemental data forms.

(5) At least one helicopter in each of the six operational classifications should be instrumented and monitored as above and flown through the maneuvers anticipated in future usage.

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APPENDIX A
DATA PROCESSING

RECORDED PARAMETERS

During the SEA operational usage surveys conducted on the five helicopter models, specific parameters were recorded on each model, as listed in Table A-1. Since lateral cyclic stick and rudder positions were not recorded, turns and control reversals could not be directly discerned in the oscillogram trace patterns. However, by using the existing parameters and others derived from them, all mission segments and virtually all flight conditions were identified for the subsequent development of the mission profiles.

TABLE A-1. IN-FLIGHT PARAMETERS RECORDED FOR EACH HELICOPTER TYPE

Parameter	UH-1H	CH-54A	CH-47A	OH-6A	AH-1G
Altitude	X	X	X	X	X
Airspeed	X	X	X	X	X
O.A.T.	X	X	X	X	X
n_x	X	X	X	X	X
n_y	X	X	X	X	X
n_z	X	X	X	X	X
Rotor Speed	X	X	X	X	X
#1 Engine Torque	X	X	X	X	X
#2 Engine Torque		X	X		
Longitudinal Cyclic Stick Position		X	X	X	X
Lateral Cyclic Stick Position					
Collective Stick Position		X	X	X	X
Longitudinal Boost Tube Axial Load	X				
Lateral Boost Tube Axial Load	X				
Collective Boost Tube Axial Load	X				
Time	X	X	X	X	X

DATA EDITING AND REDUCTION

For the application of the FCR method to the data sample, 10 mission segments and 22 flight conditions were defined and various editing criteria were formulated. For each flight condition, Table A-2 lists the general oscillogram trace characteristics and the mission segments in which the flight condition could occur.

The 10 mission segments are as follows: (1) ground operation, (2) hover, (3) ascent, (4) level flight, (5) descent, (6) autorotation, (7) in ground effect (IGE) maneuver, (8) takeoff power climb, (9) full power climb, and (10) partial power descent. As observed on the oscillogram traces, the mission segments had the following identification criteria: Ground operation was identified by steady zero airspeed and altitude at ground level; both engine torque and rotor speed were normally at ground idle values; and the vertical acceleration was smooth as compared with that during flight. Hover was identified by approximately zero knots airspeed, steady altitude, and longitudinal cyclic control movement varying about a steady mean; in addition, the vertical acceleration varied slightly about a mean. Identified by altitude increasing at a rate greater than 300 feet per minute, ascent included all climbs that did not fall into the categories of full power climb or takeoff power climb. Level flight was identified by relatively steady control positions, altitude, torque pressure, vertical acceleration, and rotor speed. Identified by altitude decreasing at a rate greater than 300 feet per minute, descent included all descents that were not partial power or a result of autorotation. Autorotation was identified by decreasing altitude, a high rate of descent, and a low engine torque pressure. IGE maneuver was identified by rapidly varying torque pressure, erratic cyclic and collective stick movement, fluctuating airspeed, and much vertical acceleration activity.

TABLE A-2. FLIGHT CONDITIONS CONSIDERED IN THE FCR TECHNIQUE

Flight Condition	Mission Segment(s) In Which Flight Condition May Occur	Characteristics of the Flight Condition
Rotor Start	1	Torque and rotor rpm increase from zero values.
Steady State	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	Torque, rpm, sticks, and A/S are steady or varying slightly about a steady mean.
Transient	1	Period of rapidly varying torque and rpm.
Takeoff	2, 3, 8, 9	N_z change from ground to air; collective and torque increasing to steady means.
Collective Pushover	2, 3, 4, 5, 6, 7, 8, 9, 10	Collective decrease to terminate or reduce ascent or to initiate or increase descent; torque decrease; negative n_z peak.
Collective Pull-Up	2, 3, 4, 5, 6, 7, 8, 9, 10	Collective increase to initiate level flight or ascent or to decrease rate of descent; torque increase; positive n_z peak.
Flare	5, 6, 10	Same as a collective pull-up but occurring in ground effect immediately before landing or hover.
Touchdown	2, 5, 6, 10	N_z changes from flight to ground characteristics.
Rotor Stop	1	Torque and rotor speed decrease to zero values.
Cyclic Pushover	2, 3, 4, 5, 6, 7, 8, 9, 10	Forward longitudinal cyclic to terminate or reduce ascent or to initiate descent while in flight; negative n_z peak.
Cyclic Pull-Up	2, 3, 4, 5, 6, 7, 8, 9, 10	Aft longitudinal cyclic to initiate ascent while in flight or to terminate or decrease rate of descent; A/S decrease and/or torque increase; positive n_z peak.
Longitudinal Reversal	2, 3, 4, 5, 6, 7, 8, 9, 10	Longitudinal stick position peak exceeding 10% full stick deflection and not related to another flight condition.

TABLE A-2 - Concluded

Flight Condition	Mission Segment(s) In Which Flight Condition May Occur	Characteristics of the Flight Condition
Ground Taxi	1	N_z will not be characteristic of ground conditions, and torque value is less than during hover.
Initiation of Ascent	2, 3, 7, 8, 9	Collective input, torque increase, positive n_z peak and cyclic stick forward movement.
Mission Segment Change w/o Maneuver	3, 4, 5, 8, 9, 10	No obvious pull-up or pushover between mission segments.
Power to Autorotation	6	Torque goes from a normal level to near zero very rapidly. The collective is rapidly decreased and a negative n_z peak may occur.
Autorotation to Power	6	Collective will increase from nearly full down position to a normal position. Torque will rapidly increase and a positive n_z peak may occur.
Dive	5, 10	Initiation of the dive consists of cyclic and/or collective stick movements followed by rapidly decreasing altitude and increasing airspeed.
Dive Pull-Out	3	Much like a pull-up with a dive preceding it, a large positive n_z peak, and a leveling and/or increase of altitude.
Cargo Pickup	2	Collective increases, torque increases, airspeed and altitude remain constant and near zero.
Cargo Drop	2, 5, 10	Collective decreases, torque decreases and airspeed and altitude remain constant and near zero.
Unknown Condition	3, 4, 5, 6, 7, 8, 9, 10	An area on the oscillogram that cannot be identified as another flight condition as defined in the flight condition criteria. The condition is initiated when the n_z trace leaves normal and is terminated when the n_z trace returns to normal.

For the mission segments based on engine power levels (takeoff power climb, full power climb, and partial power descent), power levels were established by using the functional relationship between engine shaft horsepower, main rotor speed, and torque pressure. (Engine torque equations in terms of shaft horsepower and main rotor speed are detailed in Appendix C.) Then the values of the torque pressure levels were calculated by assuming that takeoff power was military power, full power was maximum continuous power, and partial power was 40 percent of takeoff power. As listed in Table A-3 for each helicopter model, the resultant power levels were converted to corresponding trace deflections. Then these deflections were inscribed in a transparent overlay that was used in the editing process to distinguish the takeoff power climb, full power climb, and partial power descent segments according to these power levels.

TABLE A-3. POWER BANDS FOR EACH HELICOPTER TYPE

	Takeoff Power		Full Power		Partial Power	
Helicopter	Shaft Horsepower	Torque Pressure	Shaft Horsepower	Torque Pressure	Shaft Horsepower	Torque Pressure
UH-1H	1100	47.4 PSI	900	38.4 PSI	4[illegible]	19.8 PSI
OH-6A	252.5	68.2 PSI	214.5	57.7 PSI	101	29.3 PSI
AH-1G	1100	47.4 PSI	900	38.4 PSI	440	19.8 PSI
CH-47A	2300	800 LB-FT	1950	678 LB-FT	920	320 LB-FT
CH-54A	4800	91.8 %	4430	84.7 %	1920	36.7%

Examples of oscillogram sections illustrating unusual flight conditions and mission segments are presented in Figures A-1, A-2, and A-3. By observing the altitude, torque, and vertical acceleration traces and the general trend of the other traces, the oscillogram data were separated into mission segments. After the mission segments were demarcated, the flight conditions were identified. The flight conditions were recognized by identifying the characteristics listed in Table A-2 and by noting the amount and direction of change of the collective stick, longitudinal stick, engine torque, airspeed, and vertical acceleration traces. Figure A-1 depicts an AH-1G flying a combat assault mission. The aircraft performed a dive followed by a pullout. The dive is distinguished by the rapidly decreasing altitude and increasing airspeed. The dive

pullout resembles a collective pull-up but occurred at the end of the dive as indicated by the decrease of the airspeed and the rate of descent. Although this pullout was initiated during descent and terminated during ascent, it was identified as having occurred during ascent only to be consistent with the FCR technique definitions where all dives are associated with descent and all pullouts with either ascent or level flight to prevent the overlap of mission segments.

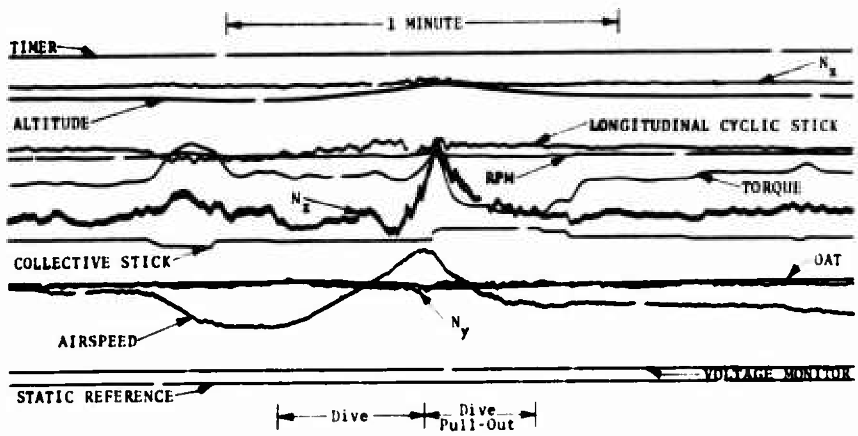

Figure A-1. Oscillogram Showing Dive.

An armed OH-6A aircraft flying a combat assault mission is depicted in Figure A-2. The aircraft performed an IGE maneuver. In this figure, the two flight conditions labeled "unknown" were probably turns because of the sustained excursion of the vertical acceleration trace. However, they had to be so labeled without evidence of the lateral cyclic stick and rudder positions.

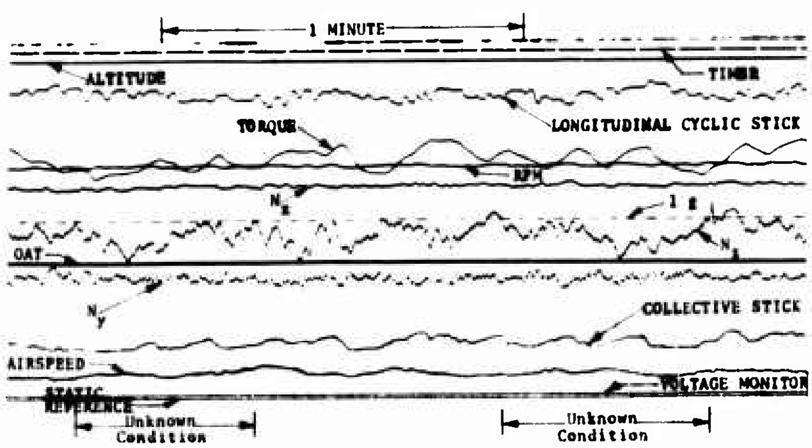

Figure A-2. Oscillogram Showing IGE Maneuvers.

Figure A-3 depicts a practice autorotation performed by a CH-47A helicopter. The power-to-autorotation flight condition is identified by the rapidly decreasing engine torque, the decreasing collective stick position, and the negative vertical acceleration peak. After the power-to-autorotation transition, there is a period of steady autorotation followed by an autorotation-to-power transition. The other flight conditions were identified similarly as in the above three examples.

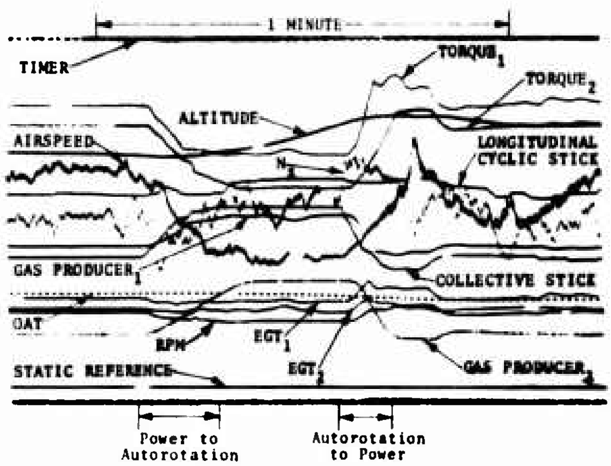

Figure A-3. Oscillogram Showing Autorotation.

In addition to the identification of flight conditions and mission segments, the oscillogram data were edited and reduced for other information: The durations of the flight conditions were measured, and the average duration for each flight condition category was computed. However, two flight conditions, steady state and unknown, which occurred frequently and were generally either very short or very long in duration, were simply separated into three duration categories: minimum, average, and maximum.

Taxi loads were defined as the maximum vertical acceleration peaks occurring in the ground operation mission segment. Only those peaks falling outside a threshold of ±0.05g about the 1.0g mean were measured. After the peaks were placed in 0.05g-increment ranges, they were grouped in gross weight ranges by using the weights listed on the supplemental data sheets.

The landing impact loads were defined as the first positive vertical acceleration peak at touchdown. While measured and tabulated as the taxi loads, the impact loads were also categorized as having occurred after a descent or a hover.

All in-flight vertical acceleration peaks that fell outside the threshold of ±0.2g about a 1.0g mean and the

durations of their excursions were measured and categorized by the concurrent mission segment and flight condition.

From the fuel, cargo, and passenger weights at takeoff and landing, as logged on the supplemental data sheets, the gross weight was computed for the start and end of each mission. A constant rate of fuel consumption was assumed to obtain the average weight-loss rate that was used to compute the instantaneous gross weight. Weight gains or losses because of cargo or passenger changes were introduced at times noted on the supplemental data sheets.

By using a reference c.g. limit as a reference datum for the basic aircraft, by using information on the number of passengers, cargo weight, etc., listed on the supplemental data forms, and by making judgments on the cargo and passenger c.g.'s given in the operator's manuals, the aircraft c.g. was computed as a function of fuel, passenger, and cargo weight. In addition, by using the supplemental data, the instantaneous gross weights, and the recorded flight time, the aircraft c.g. position and the percentage of flight time in coincident aircraft gross weight and c.g. ranges were determined. Appendix B details the methods employed to derive these parameters.

In addition, the UH-1H data were separated into utility and assault missions according to the information on the supplemental data sheets. Flights listed as direct combat support, streamliner, and special were classified as utility missions, and those listed as combat assault, command and control, and ELSA were classified as assault missions.

To establish the frequency spectrum of each flight condition, the number of flight condition occurrences in each mission segment were tabulated and the durations of the flight conditions were measured and averaged. After the average durations were calculated, the time per 100 hours for each mission profile totaled more or less than 100 hours because of the averaging process. Consequently, the time for the number of flight condition occurrences was normalized to a 100-hour data base.

APPENDIX B
PROCEDURES FOR COMPUTING PERCENTAGES OF TIME IN COINCIDENT GROSS WEIGHT AND C.G. RANGES

For each of the five SEA helicopter models, the c.g. position during flight was determined as a function of cargo, fuel, passenger, and armament weights and locations and their time-related changes according to the data given in the supplemental data sheets and operator's manuals.[15-19] The data sheets listed the basic weight of the aircraft, number of passengers, amount of cargo, amount of armament, quantity of fuel, flight time, time and type of weight changes, and number of firing runs when applicable. The operator's manuals provided information on the location of armament, passengers, cargo, and fuel.

Preparatory to determining the percentage of time in coincident gross weight and c.g. position ranges, Tables B-1 through B-5 were prepared for the helicopter models. Except for the cargo c.g. for the CH-47A, the table for each model consists of the weight, moment index, and c.g. position of each of the following: basic aircraft; oil; crew; passengers, if any; armament, if any; special equipment, if any. Except for the basic aircraft c.g. and the CH-54A cargo c.g., all information was taken from the supplemental data sheets and the operator's manuals. Because of the lack of information, a "reference" basic aircraft c.g. was assumed for each model, and the cargo in the CH-54A was assumed to be suspended at Station 133 since this model had sling loads. To account for the unknown cargo c.g. positions in the CH-47A, Table B-6 was prepared as follows. It was determined that light cargo loads could be placed anywhere

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[15] OPERATOR'S MANUAL: ARMY MODEL AH-1G HELICOPTER, Technical Manual 55-1520-221-10, Headquarters, Department of the Army, Washington, D.C.

[16] OPERATOR'S MANUAL: ARMY MODEL CH-47A HELICOPTER, Technical Manual 55-1520-209-10, Headquarters, Department of the Army, Washington, D.C.

[17] OPERATOR'S MANUAL: ARMY MODEL CH-54A HELICOPTER, Technical Manual 55-1520-217-10, Headquarters, Department of the Army, Washington, D.C.

[18] OPERATOR'S MANUAL: HELICOPTER, OBSERVATION, OH-6A (HUGHES), Technical Manual 55-1520-210-10, Headquarters, Department of the Army, Washington, D.C., December 1967.

[19] OPERATOR'S MANUAL: ARMY MODEL UH-1D/H HELICOPTERS, Technical Manual 55-1520-210-10, Headquarters, Department of the Army, Washington, D.C., August 1971.

with the aircraft c.g. remaining within permissible limits. But as the cargo weight increased, the permissible placement area decreased. Consequently, a family of curves of aircraft c.g. versus cargo c.g. for progressive cargo weight ranges was plotted to yield the data in Table B-6. This table lists the permissible cargo station placement range and assumed cargo c.g. position for each cargo weight range. Thus, from the corresponding cargo weight and station placement ranges, the aircraft c.g. positions could be calculated and the time in the various aircraft c.g. ranges could be accumulated.

TABLE B-1. AH-1G BASIC WEIGHT AND MOMENT INFORMATION

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	5784	11625.8	201.0
Oil	23	54.0	234.1
Gunner	200	166.0	83.0
Pilot	200	270.0	135.0
Emergency Radio	5	6.8	135.0
Tool Kit	4	3.3	83.0
Flares	22	18.3	83.0
	6238	12144.2	194.7

Hog Armament:	Weight	Moment	C.G.
250 Rds, 40mm	190	215	113.2
52 2.75 Rockets	1122	2244	200.0
2000 Rds, 7.62mm	130	141	108.5
Wing Delivery System	307	612	199.3
	1749	3212	183.6

Scout Armament:	Weight	Moment	C.G.
200 Rds, 40mm	152	172	113.2
38 2.75 Rockets	820	1640	200.0
3000 Rds, 7.62mm	195	211	108.2
XM-18	166	334	201.2
Wing Delivery System	694	1370	197.4
	2027	3727	183.9

TABLE B-2. CH-54A BASIC WEIGHT AND MOMENT INFORMATION

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	20493	7152.1	349
Oil	15	4.0	234
Pilot	200	19.0	94
Copilot	200	19.0	94
Aft Pilot	200	26.0	130
Cargo Hndlg. Equip.	1350	466.0	345
	22458	7686.1	342.2

TABLE B-3. OH-6A BASIC WEIGHT AND MOMENT INFORMATION

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	1224	1346.4	110.0
Oil	7	9.1	130.0
Misc.	50	54.0	108.0
Normal Crew	400	294.0	73.5
	1681	1703.5	101.3

Armament:	Weight	Moment	C.G.
Mini-Gun	106	97.5	92.0
M-60	25	26.3	105.0
M-16	10	7.4	73
2000 Rds, 7.62mm	130	119.6	9[illegible]
500 Rds, 7.62mm	35	36.8	105.0
Grenades	50	54.0	108.0
	356	341.6	96.0

TABLE B-4. UH-1H BASIC WEIGHT AND MOMENT INFORMATION

A/C#70-15816

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	5339.7	8009.6	150.0
Oil	27.3	47.2	173.0
Recorder	25.0	47.5	190.0
Mini-Gun	220.5	313.1	142.0
Normal Crew	480.0	228.5	47.6
	6092.5	8645.9	141.9

A/C#70-15714

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	5336.0	8004.0	150.0
Oil	27.3	47.2	173.0
Recorder	25.0	47.5	190.0
Mini-Gun	220.5	313.1	142.0
Normal Crew	433.6	206.4	47.6
Normal Crew	433.6	368.6	85.0
	6476.0	8986.8	138.8

TABLE B-5. CH-47A BASIC WEIGHT AND MOMENT INFORMATION

Basic Aircraft:	Weight	Moment	C.G.
Basic Weight	18659	6512.0	349.0
Oil	28	13.5	480.7
Pilot and Copilot	400	29.8	74.5
Flight Engineer	200	21.0	104.9
	19287	6576.3	341.0

TABLE B-6. CH-47A TRANSPORT CARGO WEIGHT, LOCATION, AND MOMENT INFORMATION

Cargo Weight (lb)	Allowable Station Location	Assumed Center of Gravity
0	486-120	303
1000	486-120	303
2000	486-120	303
3000	448-138	293
4000	423-180	302
5000	408-208	308
6000	400-224	312
7000	392-238	315

After preparing the foregoing tables, the following was computed for each flight of each helicopter model. To the basic weight in Tables B-1 through B-5 were added for the outset of each flight the weights for cargo and fuel; the summed weights were also modified for any changes from the listed passenger, armament, and special equipment values. Next, with an assumed constant rate of fuel consumption and with allowances made for changes in passenger, armament, and cargo weights and c.g. positions, various references were used to determine moment and then c.g. changes as a function of time. Then time was accumulated in coincident gross weight and c.g. ranges. With the assumption that the time in the c.g. ranges could reasonably be normally distributed and after computing a mean and standard deviation for each gross weight range, the time was distributed normally over the c.g. ranges. From these results were computed the percentages of time in the coincident gross weight and c.g. ranges as listed in Tables 4, 9, 14, 19, 24, and 29.

APPENDIX C
ENGINE TORQUE EQUATIONS

To define full power climbs, takeoff power climbs, and partial power descents requires knowing the engine torque which is based on its relationship with the shaft horsepower and rotor speed. The engine torque equations for the five SEA helicopter models are as follows:

As derived in Appendix II of Reference 6, the equation for both the UH-1H and the AH-1G is

$$Q_P = \frac{SHP_E}{6.89\text{x}10^{-2}\ N_R} - 1.88 \qquad \text{(C-1)}$$

where Q_P = torque pressure, psi

SHP_E = engine shaft horsepower, HP

N_R = rotor speed, rpm

Also as derived in Appendix II of Reference 6, the equation for the OH-6A is

$$Q_P = \frac{SHP_E}{7.046\text{x}10^{-3}\ N_R} - 1.481 \qquad \text{(C-2)}$$

where Q_P = torque pressure, psi

SHP_E = engine shaft horsepower, HP

N_R = rotor speed, rpm

The equations for the CH-47A and CH-54A were derived by assuming that the curves of shaft horesepower versus torque for specific rotor speeds as presented in References 16 and 17, respectively, were linear.

The equation for the CH-47A is

$$Q = \frac{SHP_E}{1.25\text{x}10^{-2}\ N_R} \qquad \text{(C-3)}$$

where Q = engine torque, ft-lb

The equation for the CH-54A is

$$Q_I = \frac{SHP_E}{0.4371\ N_R + 4.191} \qquad (C-4)$$

where Q_I = indicated torque, %